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OFFICE OF CHEMICAL SAFETY AND POLLUTION PREVENTION

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MEMORANDUM

Subject: Registration Review: Ecological Risk Assessment for Terbufos

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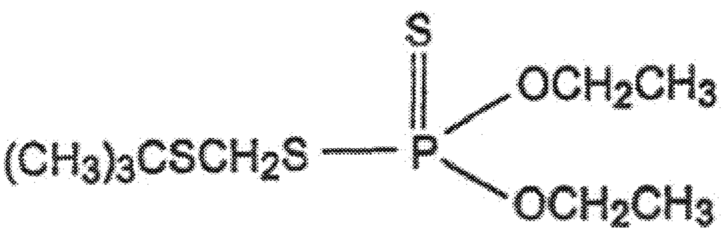
The Environmental Fate and Effects Division (EFED) conducted an ecological risk assessment for the Registration Review of terbufos, a systemic organophosphate used as an insecticide and nematicide to control a variety of pests on corn, sorghum, and sugar beet. The assessment is attached.

REGISTRATION REVIEW

ECOLOGICAL RISK ASSESSMENT AND EFFECTS DETERMINATION

Terbufos



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I. Executive Summary

Terbufos is a systemic organophosphate insecticide-nematicide used to control a variety of pests on corn (field and sweet corn), grain sorghum, and sugar beet. Terbufos was first registered in 1974 and was most recently reviewed in 1999 (USEPA, 1999; reregistration eligibility decision document (RED)). Previous risk assessments concluded that ecological risks to aquatic and terrestrial organisms were of concern to the Agency. Specifically, the fish kill incidents associated with the use of terbufos on corn was a major consideration in the risk mitigation plan outlined in the 2001 Interim Reregistration Eligibility Decision (IRED; USEPA, 2001) for terbufos. Mitigation efforts included a reduction in the application rate for sorghum, a label requirement for maintaining setbacks and vegetative buffers adjacent to terbufos treated areas, the removal of the "over the top" application for European corn borer control on corn, and a label change for banded applications on corn (use a 7 inch band over the row, in front of the press wheel, and incorporate into the top 1 inch of soil).

The relatively high vapor pressure (3.16E-04 mm Hg at 25°C) and Henry's Law Constant (2.46 E-05 atm m^3/mol) of terbufos suggest that some of the parent compound will dissipate by volatilization from moist soil and water bodies into the atmosphere. Terbufos is also susceptible to degradation and transformation by both abiotic and biotic processes. Terbufos is moderately mobile to slightly mobile in soil. Three major degradates were identified in the environmental fate studies: terbufos sulfoxide, terbufos sulfone, and formaldehyde. Terbufos sulfoxide and terbufos sulfone have low soil partition coefficient (K_d) values ranging from 0.40 to 2.93 mL/g and DT_{50s} of 136 to 174 days in soil suggesting that they are more mobile and persistent than terbufos in the environment.

Terbufos is very highly toxic to fish, aquatic invertebrates, and mammals, highly toxic to birds, and moderately toxic to bees on an acute basis. Chronic effects are observed in both aquatic and terrestrial animals at low concentrations. Some effects are observed in plants; however, toxicity to plants is relatively low compared to animals. Available data indicate that two major degradates (terbufos sulfoxide and terbufos sulfone) are similar to terbufos in toxicity; thus, they are considered degradates of concern. Field data show avian and mammalian mortality associated with terbufos use. In addition, there are a large number of reported fish kills attributed to the use of terbufos.

This assessment considers the most up to date toxicology and fate data, uses current exposure models including those exploring pathways not quantitatively assessed in past risk assessments (*e.g.*, drinking water and inhalation exposure), and considers the most recent labels (including a newer formulation, 20G), incident information, and monitoring data. Based on the latest information, conclusions of this assessment are substantially similar to those of the RED. An acute and chronic risk concern is expected for direct effects to both listed and non-listed species of birds, mammals, fish, aquatic invertebrates, and terrestrial invertebrates. The Agency does not currently have the capability to quantitatively assess the effectiveness of the required vegetative buffers; however, based on a review of research studies it was hypothesized that buffers may reduce the loading of total toxic residues of terbufos in aquatic systems between 50% and 90%. Although loading may be reduced up to 90%, the overall risk concerns for fish and aquatic invertebrates remain because risk quotients (RQs) remain above the levels of concern (LOC) after accounting for those reductions. Previous assessments did not consider risk to plants due to a lack of data. This assessment concludes that there is not a risk concern for direct effects to aquatic and terrestrial plants. In conclusion, consistent with past assessments there is a risk concern for aquatic organisms and terrestrial wildlife including listed species for the labeled uses of terbufos.

Table 1. Summary of Direct and Indirect Effects Associated with Registered Uses of Terbufos

Taxon	Risk Concern for Direct Effects?		Risk Concern for Indirect Effects to Listed Species?
	Non-Listed	Listed	
Birds, reptiles, and terrestrial-phase amphibians	**Yes**	**Yes**	**Yes**
Mammals	**Yes**	**Yes**	**Yes**
Terrestrial invertebrates (honeybees)[1]	**Yes**	**Yes**	**Yes**
Terrestrial (upland and semi-aquatic) plants – monocots	No	No	**Yes**
Terrestrial (upland and semi-aquatic) plants – dicots	No	No	**Yes**
Freshwater fish and aquatic-phase amphibians	**Yes**	**Yes**	**Yes**
Marine/estuarine fish	**Yes**	**Yes**	**Yes**
Freshwater invertebrates	**Yes**	**Yes**	**Yes**
Marine/estuarine invertebrates	**Yes**	**Yes**	**Yes**
Aquatic vascular plants	No	No	**Yes**
Aquatic non-vascular plants	No	N/A	N/A

[1] Honeybee is used as a surrogate for terrestrial invertebrates. Honeybees were not assessed quantitatively due to a lack of oral (dietary) toxicity data for adults or larvae; however, risk is expected for terrestrial invertebrates given that terbufos is an insecticide.

N/A = Not applicable. There are no aquatic non-vascular plant species that are listed at this time.

II. Use Characterization and Methods of Application

Terbufos is used on corn, sorghum, and sugar beet to control a variety of insects and nematodes. Use data from 2004-2012 indicate an annual average domestic use of approximately 740,000 pounds of terbufos active ingredient (USEPA, 2014). Terbufos is applied in bands, in-furrow, or knifed-in. All uses require ground application and soil incorporation to a specified depth depending on the use. The timing of application is at-planting, at-bedding, postemergence, or at cultivation. Terbufos is applied only one time a year for all uses. The labels provide rates in terms of lb ai/A and lb ai/1000 ft row. On a per acre basis, the maximum application rate for corn is 1.3 lb ai/A except for a Special Local Need (SLN) registration (NC920001) in North Carolina that allows use on corn up to 2.6 lb ai/A. The maximum application rates for sorghum and sugar beet are 1.695 lb ai/A and 1.96 lb ai/A, respectively. Use information was obtained from the chemical profile produced by the Biological and Economic Analysis Division (BEAD). EFED used application scenarios that result in maximum exposure from a given use for the risk assessment.

In addition to the technical product, there are three registered end-use granular formulations: Counter®CR (EPA Reg. No 241-314), Counter®15G (EPA Reg. No. 5481-545), and Counter®20G (EPA Reg. No. 5481-562).

As a result of the terbufos IRED (USEPA, 2001), setbacks and buffers were added to terbufos product labels. The following distances are to be maintained: (1) a 500 ft vegetative buffer between the treated area and surface water on neighboring land, (2) a 500 ft vegetative buffer between a standpipe drain outlet and surface water on neighboring land, (3) a 66 ft setback between the treated area and entry points to surface water bodies on non-highly erodible soils and a 300 ft setback on highly erodible soils, (4) a 66 ft setback between the treated area and standpipes on terraced fields as well as a 66 ft vegetative buffer between the tile outlet and surface water bodies, and (5) a restriction on loading, rinsing, and washing equipment within 300 ft of surface water bodies or within 50 ft of wells unless conducted on an impervious surface. All setbacks must be planted with a crop or seeded with grass or other suitable cover. All vegetative buffers must be seeded with grass or other suitable cover.

III. Summary of Environmental Fate

3.1 Terbufos

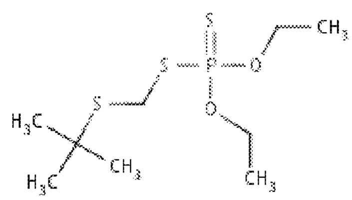
Selected physical, chemical and environmental fate properties of terbufos are listed in **Table 2**. The solubility of terbufos in water is 5.4 mg/L at 25°C. The relatively high vapor pressure (3.16E-04 mm Hg at 25°C) and Henry's Law Constant of 2.46 E-05 atm m^3/mol suggest that terbufos will dissipate by diffusion from moist soil and water into the atmosphere, but the amount that may volatilize will vary depending on the use site conditions and the application method. Volatilization may be a major dissipation route for terbufos that remains on the soil surface after incorporation. However, vapor-phase terbufos is susceptible to atmospheric degradation by reaction with photochemically-produced hydroxyl radicals; the half-life in air is estimated to be 0.53 hours (EPISUITE 4.1). Terbufos residue were not detected in rain or snow samples monitored in several states (IA, IN, NY, OH and WV) (Majewski and Capel, 1995).

Terbufos is susceptible to transformation by both abiotic and biotic processes. All DT_{50} values were calculated using nonlinear regression and single first order (SFO), double first order in parallel (DFOP), or intermediate order rate equation (IORE) equations (USEPA, 2012a). **Appendix A** provides estimated DT_{50s} for the submitted environmental fate studies. The hydrolysis half-life for terbufos is less than 2 days in the typical range of environmental pH values (5, 7, and 9). In another study, terbufos hydrolyzed with a half-life of less than 2 weeks at pH 4, 7, and 9. However, in an aerobic aquatic metabolism study, terbufos degraded in the water column with a half-life of less than 2 days, which is consistent with the results from the recent hydrolysis study (MRID 44862502). The metabolic half-life of terbufos in aerobic soil ranges from 5.9 to 10.2 days and in anaerobic soil is 67.5 days. Kd values ranging from 5.42 to 14.6 mL/g suggest that terbufos is moderately mobile to slightly mobile in soil, according to a classification scheme of the Food and Agricultural Organization of the United Nations (USEPA, 2006a).

The terrestrial field data indicate that terbufos dissipated in the field with half-lives of 6.01 days in loamy soil from Illinois, 56.8 days in sandy loam soil from Colorado, and 22.2 days in sandy loam from California. Except for the Colorado soil, these half-lives are comparable to findings from the aerobic soil metabolism study discussed above (DT_{50s} <11 days). Data from the open literature (Felsot, et al., 1982) reported field half-lives of 11-16 days for terbufos in silt loam and silty clay loam soils when terbufos was applied at a rate of 1.0 lb ai/A.

The log K_{OW} (*n*-Octanol–water partition coefficient) of 4.71 indicates potential bioaccumulation of terbufos in aquatic organisms. The maximum terbufos bioaccumulation factors in bluegill sunfish were 320, 940, and 680X in edible tissues, non-edible tissue, and whole fish, respectively. At the end of the 14-day depuration period, the reduction in residues was 84% for fillet tissue and 93% for visceral tissue and whole fish. The single first order elimination rate was calculated as $K_T = 0.31\ d^{-1}$ (DT_{50} = 2.24 days). Two major metabolites were identified: terbufoxon (CL94221) and a methane related compound (CL202474).

Table 2. Physical, Chemical and Environmental Fate Properties of Terbufos

Property	Value	Source (Classification)
Common name	Terbufos	MRID 41297901
CAS Registry No.	13071-79-9	---
PC Code	105001	---
Chemical name (CAS)	S-[[(1,1-dimethylethyl)thio]methyl]O,O-diethylphosphorodithioate	MRID 41297901
SMILES notation	CCOP(=S)(OCC)SCSC(C)(C)C	EPISUITE 4.1[1]
IUPAC name	*S-tert*-butylthiomethyl *O,O*-diethyl phosphorodithioate	TOXNET
Synonyms	CL 92100, AC 92100	MRID 41373604 and 44862501
Structure		TOXNET
Molecular formula	$C_9H_{21}O_4P_1S_3$	MRID 41297901
Physical and Chemical Properties		
Molecular weight	288.4	MRID 41297901
Physical state	Clear liquid	MRID 41049502 (Acceptable)
Vapor pressure	3.16 x 10^{-4} mm Hg (25°C) 6.98 x 10^{-4} mm Hg (35°C) 12.4 x 10^{-4} mm Hg (45°C)	MRID 41049502 (Acceptable)
Henry's Law constant	2.22E-05 atm m^3/mol	USEPA, 2009

Property	Value	Source (Classification)
Specific gravity/density	1.11g/ml @ 20ºC	MRID 41049502 (Acceptable)
Solubility in water	5.4 mg/L @ 25ºC in distilled water 5.6 mg/L in water solution buffered at pH 7 4.5 mg/L in water solution buffered at pH 10	MRID 41049502 (Acceptable)
log K_{ow}	4.71	MRID 41049502 (Acceptable)
Laboratory accumulation in fish bioaccumulation factor (BCF) (*Lepomis macrochirus*)	320X in edible tissues 940X non-edible (viscera) tissues 680X whole fish At the end of the 14-day depuration period, the reduction in residues was 84% for edible tissue, 93% for whole fish, and 93%for visceral tissue.	MRID 41373606 and 41773605 (Acceptable)
Environmental Fate Properties		
Hydrolysis half-life pH = 4 pH = 7 pH = 9 pH = 5 pH = 7 pH = 9	 11.2 days (SFO) @ 25˚C 11.4 days (SFO) @ 25˚C 13.1 days (SFO) @ 25˚C 2.52 days (SFO) @ 20˚C *[1.8 days (SFO) @ 25˚C]*[2] 2.17 days (SFO) @ 20˚C *[1.5 days (SFO) @ 25˚C]*[2] 2.56 days (SFO) @ 20˚C *[1.8 days (SFO) @ 25˚C]*[2] Major Degradate Formaldehyde (Max 96.1% @ day 1.6; pH 9.0)	MRID 00087694 (Acceptable) MRID 44862501 (Acceptable)
Photolysis half-life in air	0.53 hours (12 hour day; 1.5E6 OH/cm^3)	EPISUITE4.1[1]
Photolysis half-life in water	1.77 days (SFO) @ 25˚C Major Degradate Formaldehyde (Max 71.9% @ day 6)	MRID 00161567 and 41181101 (Supplemental)
Aerobic soil metabolism half-life (25 °C)	5.85 days (silt loam) (SFO) @ 25 °C 10.2 days (silt loam) (SFO) @ 25 °C Major Degradates Terbufos Sulfoxide (Max 52.3 % @ day 30) Terbufos Sulfone (Max 20.1 % @ day 60) CO_2 (Max 46 % @ day 365)	MRID 00156853 and 41749801 (Acceptable)

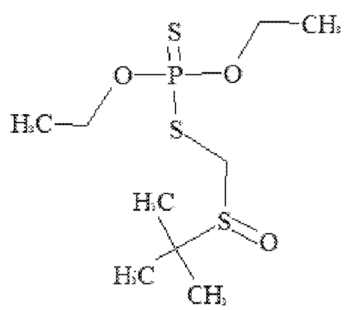
Property	Value	Source (Classification)
Anaerobic soil metabolism half-life	67.5 days (Silt loam) (SFO) @ 25 °C Volatile organic residue 38.6% @ day 60 Major degradates Terbufos Sulfoxide (Max 10.5% @ day 15) CO_2 (Max 53 % @ day 60)	MRID 41749801 (Acceptable)
Aerobic aquatic metabolism half-life for total system	Total System Loam sediment 24.2 days (IORE (20±2°C) *[19.7days (IORE) @ 25°C]* [2] Sand Sediment [3.66 days (SFO) @ (20±2°C)] [3] *[2.6 days (IORE) @ 25°C]* [2,3] Volatile organic residue (41.5% @ day 30) Major degradates Terbufos Sulfoxide (Max 11% @ day 100) CO_2 (Max 53 % @ day 100)	MRID 44672004 (Supplemental)
Aerobic aquatic metabolism half-life in aqueous phase (natural pond water)	0.762 days (IORE) @ 20±2°C *[0.6 days (IORE) @ 25°C]* [2] 1.03 days (SFO) @ 20±2°C *[0.8 days (IORE) @ 25°C]* [2] Major Degradate Degradate A (unidentified) (Max 33.8% @ day 2) CO_2 (Max 43.6% @ day 30)	MRID 44862502 (Supplemental)
Soil adsorption coefficient K_d (L/kg)	<u>Adsorption</u>[4] K_d (L/kg) 5.42 (AR Loamy sand) 11.4 (IN Silt loam) 13.0 (NJ Sandy loam) 14.6 (WI Loam)	MRID 41373604 (Acceptable)
Terrestrial field dissipation half-life	6.01 days (IORE) in Arcola, IL 56.8 days (IORE) in Greeley, CO 22.2 days (IORE) in Hanford, CA No major degradates were reported	MRID 00087708 (Acceptable) MRID 00087706 (Acceptable) MRID 41883101 (Supplemental)

[1] http://www.epa.gov/opptintr/exposure/pubs/episuite.htm
[2] DT_{50}s values are Arrhenius-adjusted temperature @ 25°C for exposure model inputs.
[3] DT_{50}s values are recommended. DT_{50s} model inputs from the kinetic guidance.
[4] Since the correlation (r^2) between organic carbon and K_d is 0.33, Koc is not appropriate for terbufos.

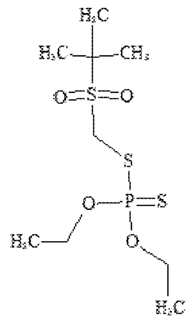
3.2 Terbufos Degradates

Three major degradates, excluding CO_2, were identified in the environmental fate studies: terbufos sulfoxide (maximum 52.3%), formaldehyde (maximum 96.1%), and terbufos sulfone (maximum 20.1%). Limited data are available on persistence and mobility for the degradates terbufos sulfoxide and terbufos sulfone (**Table 3**). Terbufos sulfoxide and terbufos sulfone have low K_d values ranging from 0.40 to 2.93 mL/g and DT_{50s} of 136 to 174 days in soil. These values suggest that these degradates are more mobile and persistent than terbufos in the environment. Terbufoxon, terbufoxon sulfoxide, terbufoxon sulfone, des-ethyl terbufos sulfoxide, and des-ethyl terbufos sulfone were also observed and formed less than 3.1% in environmental fate studies. The oxons (terbufoxon, terbufoxon sulfoxide, terbufoxon sulfone) were only identified in the anaerobic soil metabolism study and only as minor degradates. Although oxon degradates are more toxic than some organophosphates, ecological structure activity relationship (ECOSAR) toxicity estimates suggest that terbufos oxons are orders of magnitude less toxic than terbufos to fish and invertebrates and about an order of magnitude less toxic to algae (USEPA, 2013). Therefore, the oxons were not considered degradates of concern given the anticipated low exposure and the estimated toxicity compared to terbufos. Structures and percent formation of degradation products in various environmental fate studies are provided in **Appendix B**.

Table 3. Physical, Chemical and Environmental Fate Properties of Terbufos Sulfoxide and Terbufos Sulfone

Property	Value	Source (Classification)
Terbufos Sulfoxide		
Common name	Terbufos Sulfoxide	MRID 44862501
CAS Registry No.	10548-10-4	
Chemical name (CAS)	S-[[(1,1-dimethylethyl)sulfinyl]methyl]O,O-diethylphosphorodithioate	
SMILES notation	CCOP(=S)(OCC)SCS(=O)C(C)(C)C	EPISUITE[1]
Synonyms	CL 94301, AC 94301	MRID 41373604 and 44862501
Structure		EPISUITE[1]

Property	Value	Source (Classification)
Molecular formula	$C_9H_{21}O_3P_1S_3$	
Molecular weight	304.42	
Vapor pressure	3.42 E-05mm Hg (25°C)	
Henry's Law constant	9.13E-08 atm m^3/mol	
Solubility in water	1100 mg/L @ 20°C in distilled water	
log K_{ow}	2.21	
Hydrolysis half-life pH = 5 pH = 7 pH = 9	 33.2 days (SFO) @ 40°C *[93.9 days (SFO) @ 25°C]*[2] 23.2 days (SFO) @ 40°C *[65.1 days (SFO) @ 25°C]*[2] 18.5 days (SFO) @ 40°C *[13.3 days (SFO) @ 25°C]*[2]	MRID 44862501 (Acceptable)
Aerobic soil metabolism half-life (25°C)	136 days (Silt loam) (SFO) @ 25 °C	MRID 00156853 (Acceptable)
Soil adsorption coefficient K_d (L/kg)	Adsorption[3] K_d (L/kg) 0.4 (AR Loamy sand) 2.83 (IN Silt loam) 0.50 (NJ Sandy loam) 0.75 (WI Loam)	MRID 41373604 (Acceptable)
Terbufos Sulfone		
Common name	Terbufos Sulfone	MRID 44862501
CAS Registry No.	56070-16-7	
Chemical name (CAS)	S-[[(1,1-dimethylethyl)sulfonyl]methyl]O,O-diethylphosphorodithioate	
SMILES notation	C(C)(C)(C)S(=O)(=O)CSP(=S)(OCC)OCC	EPISUITE[1]
Synonyms	CL94320, AC 94320	MRID 41373604 and 44862501

Property	Value	Source (Classification)
Structure		EPISUITE[1]
Molecular formula	$C_9H_{21}O_4P_1S_2$	
Molecular weight	320.42	
Vapor pressure	7.88 E-06 mm Hg (25°C)	
Henry's Law constant	4.10E-08 atm m^3/mol	
Solubility in water	408 mg/L @ 19°C	
log K_{ow}	2.48	
Hydrolysis half-life pH = 5 pH = 7 pH = 9	 21.2 days (SFO) @ 40°*C* *[60.0 days (SFO) @ 25°C]* [2] 15.5 days (SFO) @ 40°*C]* *[43.8 days (SFO) @ 25°C]* [2] 14.7 days (SFO) @ 20°*C]* *[10.4 days (SFO) @ 25°C]* [2]	MRID 44862501 (Acceptable)
Aerobic soil metabolism half-life	174 days (Silt loam) (SFO) @ 25 °C	MRID 00156853 (Acceptable)
Soil adsorption coefficient K_d (L/kg)	<u>Adsorption</u>[3] K_d (L/kg) 0.55(AR Loamy sand) 2.93 (IN Silt loam) 0.69 (NJ Sandy loam) 0.86 (WI Loam)	MRID 41373604 (Acceptable)

[1] http://www.epa.gov/opptintr/exposure/pubs/episuite.htm
[2] DT_{50}s values are Arrhenius-adjusted temperature @ 25°C for exposure model inputs.
[3] Since the correlation (r^2) between organic carbon and K_d is ≤ 0.66, the Koc is not appropriate for terbufos sulfoxide and terbufos sulfone.

IV. Summary of Ecological Effects

Terbufos is moderately to very highly acutely toxic to both aquatic and terrestrial animals based on available toxicity studies. In general, studies with end use products show similar toxicity to the technical grade active ingredient (TGAI) although in some cases organisms may be slightly more sensitive to end use products. Registrant submitted toxicity studies are not available for degradation products; however, submitted ancillary information about terbufos sulfone and terbufos sulfoxide toxicity to *Daphnia magna* is discussed below in addition to data identified in the ECOTOXicology database. Available data indicate similar toxicity of terbufos, terbufos sulfone, and terbufos sulfoxide.

Toxicity endpoints and values used to calculate RQs are reported in **Table 4**. All available studies including additional details are provided in **Appendix C.** A summary of available data follows **Table 4**. Studies identified in the ECOTOXicology database that reported a more sensitive endpoint were reviewed and are also discussed below. Finally, toxicity data for mixtures (i.e., terbufos plus at least one other pesticide) were identified in the ECOTOXicology database. The majority of those studies show that terbufos enhances the toxicity of herbicides to terrestrial plants. Mixture data are summarized below and additional details are provided in **Appendix D**.

Table 4. Terbufos Toxicity Endpoints and Values Used for RQ Calculations

Species	Exposure Scenario	% AI	Toxicity	MRID
Bluegill sunfish (*Lepomis macrochirus*)	96 hr (static)	86	LC_{50} = 0.77 (0.72-0.83)[1] µg ai/L	00087718
	ELS	NA	NOAEC = 0.10 µg ai/L Estimate based on acute-to-chronic ratio using rainbow trout data[2]	NA
Waterflea *(Daphnia magna)*	48 hr (static)	88.6	EC_{50} = 0.17 (0.15-0.19)[1] µg ai/L	00101495
	21 day Life-Cycle (flow-through)	98.4	NOAEC = 0.030 µg ai/L LOAEC = 0.076 µg ai/L based on growth and reproduction (reduced body length and number of offspring)	00162525
Sheepshead minnow (*Cyprinodon variegatus*)	96 hr	98.4	LC_{50} = 1.6 (0.77-3.2)[1] µg ai/L	00162524
	ELS	NA	NOAEC = 0.14 µg ai/L Estimate based on acute-to-chronic ratio using rainbow trout data[2]	NA
Mysid shrimp (*Americamysis bahia*)	96 hr (static)	98.4	LC_{50} = 0.22 (0.14-0.35)[1] µg ai/L	00162523
	NA	NA	NOAEC = 0.041 µg ai/L Estimate based on acute-to-chronic ratio using daphnia data[2]	NA

Species	Exposure Scenario	% AI	Toxicity	MRID
Freshwater Algae (*Pseudokirchneriella subcapitata)*	96 hr (static)	89.3	EC_{50} >1.85 mg ai/L NOAEC = 0.399 mg ai/L LOAEC = 1 mg ai/L based on effects to cell density, area under the growth curve, average specific growth rate, and yield.	48689902
Duckweed *(Lemma gibba*)	7 day	89.3	EC_{50} > 4.20 mg ai/L NOAEC = 0.280 mg ai/L LOAEC = 0.630 mg ai/L based on frond number, growth rate of frond number, and yield of frond number	48689901
Northern Bobwhite Quail (*Colinus virginianus*)	Single oral dose	89.6	LD_{50} =28.6 (22.2-55.9)[1] mg ai/kg bw	00106551
	8 days (5 days treatment and 3 days observation)	86	LC_{50} = 143 (103-214)[1] ppm ai	00087717
Mallard Duck (*Anas platyrhynchos*)	Single oral dose	15	LD_{50} = 88 (0-215)[1] mg formulation/kg bw LD_{50} =13.2 (0-32.3)[1] mg ai/kg bw	40660705
	One-generation Reproduction Study	89.6	NOAEC = 5 ppm ai LOAEC = 15 ppm ai based on a possible biologically significant (but not statistically significant) effect on embryo viability.	00161574
Brown-headed Cowbird (*Molothrus ater*)	Single oral dose	20	LD_{50} = 85 (46-151)[1] mg formulation/kg bw LD_{50} = 16.9 (9.2-30.1)[1] mg ai/kg bw	41508804
Rat	Acute Oral	89.7	LD_{50} = 1.25 (0.98-1.52)[1] mg ai/kg bw (female)	44021601
		19	LD_{50} = 0.836 mg ai/kg bw (female)	47512801
	2-generation reproduction	89.6	NOAEC(L) = 1 ppm ai (0.07-0.09 mg ai/kg bw/day) LOAEC(L) = 2.5 ppm ai (0.18-0.24 mg ai/kg bw/day) based on decreased pregnancy, decreased male fertility, decreased body weight gain in adult females during lactation, and decreased pup weights	43649402
Honeybee (*Apis mellifera*)	Acute contact	TGAI	LD_{50} = 4.09 µg ai/bee	00066220
Cabbage, Carrot, Cucumber, Lettuce, Soybean, Tomato, Corn, Oat, Onion, Ryegrass	Tier 1 Seedling Emergence	89.3	EC_{25} >2.04 lb ai/A NOAEC = 2.04 lb ai/A Applies to monocots and dicots	48710801

[1]Range is 95% confidence interval.
[2] See **Table C-1**, **Appendix C**, for calculations.
ELS = Early life stage; NA = not applicable

4.1 Aquatic Organisms

Acute Toxicity to Freshwater Fish

TGAI

Several acute toxicity studies with different species are available. Toxicity may be underestimated because the available studies reported nominal concentrations and terbufos may degrade by hydrolysis and photolysis during a 96 hr exposure period. Bluegill sunfish is the most sensitive species tested with acute toxicity ranging from 96 hr LC_{50} = 0.77 to 3.8 µg ai/L (MRID 00037483, 00085176, 00087718, and 40098001). Rainbow trout acute toxicity ranged from 96 hr LC_{50} = 7.6 to 9.4 µg ai/L (MRID 00037483 and 40098001). Fathead minnow showed a 96 hr LC_{50} = 390 µg ai/L (MRID 40098001). Brown trout showed a 96 hr LC_{50} = 20 µg ai/L (MRID 00087718). Channel catfish showed a 144 hr LC_{50} = 9.6 µg ai/L (MRID 00085176). Sublethal effects included partial loss of equilibrium and pectoral fin erection; however, it is not clear if these effects were observed in surviving fish or fish that eventually died and most studies did not report any sublethal effects.

End use product

The 15% granular formulation of terbufos (Counter 15G) is comparable in acute toxicity to technical grade terbufos. The 96 hr LC_{50} = 1.8 (95% confidence interval of 1.5-2.3) µg ai/L for bluegill sunfish and the 96 hr LC_{50} = 8.9 µg ai/L (95% confidence interval of 7.2-11.1) for rainbow trout (MRID FE0TER04 and FE0TER05). Sublethal effects were not reported for surviving fish.

A second study with a 15% granular formulation of terbufos (product not specified) showed similar results (MRID 40098001) for toxicity to rainbow trout and blugill sunfish. The 96 hr LC_{50} = 1.7 (95% confidence interval of 1.2-2.4) µg ai/L for bluegill sunfish and the 96 hr LC_{50} = 8.8 µg ai/L (95% confidence interval of 6.4-12.1) for rainbow trout. Data were also reported for fathead minnow (96 hr LC_{50} = 150; 95% confidence interval of 101-223 µg ai/L) and channel catfish (96 hr LC_{50} = 1800; 95% confidence interval of 1230-2640 µg ai/L). Sublethal effects were not reported.

Chronic Toxicity to Freshwater Fish

An early life-stage study with rainbow trout (MRID 41475802) showed reduced wet weight and length at concentrations 1.4 µg ai/L and higher. A significant reduction of 60 day post hatch survival was observed at concentrations of 2.7 µg ai/L and higher. A majority of fish at 2.7 and 5.3 µg ai/L showed sublethal effects throughout the study including resting on their lateral surfaces, hypersensitivity, loss of equilibrium, irregular respiration, dark discoloration, surfacing, and quiescence. In addition, several fish in various concentrations developed spinal curvature and malformed otic capsules. The study NOAEC = 0.64 µg ai/L.

A second study with rainbow trout (MRID 40009301) did not produce a NOAEC because no effects were observed at the highest test concentration (1.4 µg ai/L).

In addition to the available registrant submitted studies, an open literature study (Call et al., 1989) was identified in the ECOTOXicology database that reported a more sensitive endpoint; therefore, the study was reviewed. The NOAEC = 0.34 µg ai/L and the LOAEC = 0.56 µg ai/L based on reduced length of juvenile fathead minnows (*Pimephales promelas*). Wet weight was reduced at higher test concentrations. The study authors questioned the biological significance of the observed effects (5-5.5% reduction) and set the study NOAEC at 1.96 µg ai/L. The study was classified as qualitative in part because of high variability in measured test concentrations. Therefore, results are not used to calculate RQ values but are incorporated into the risk characterization.

Bluegill sunfish sensitivity to terbufos on a chronic basis was estimated using an acute to chronic ratio (ACR) because it is the most acutely sensitive species. The ACR was based on rainbow trout (acute and chronic toxicity) and bluegill sunfish (acute toxicity) data (see **Table C-1** in **Appendix C** for calculation). The estimated NOAEC = 0.10 µg ai/L

Chronic Toxicity to Aquatic-phase Amphibians

One open literature study on aquatic-phase amphibians was identified in the ECOTOXicology database. Fish are typically used as surrogates for aquatic-phase amphibians; however, this study was reviewed because under-represented taxonomic classes including aquatic-phase amphibians have been selected for further refinement in preliminary risk assessments, even if these taxa show less sensitivity than surrogate species. The southern bellfrog showed delayed development (Gosner stage) and metamorphosis when exposed to 10 µg terbufos sulfone/L (nominal) for ten weeks (Choung et al., 2011a). Terbufos was not tested. The study was classified as qualitative in part because only one terbufos sulfone concentration was tested; thus, an evaluation of dose-response cannot be determined. Therefore, results are not used to calculate RQ values but are incorporated into the risk characterization.

Acute Toxicity to Marine/Estuarine Fish

Two acute toxicity studies are available for sheepshead minnow. Toxicity ranged from 96 hr LC_{50} = 1.6 to 3.2 µg ai/L (MRID 00162524 and 41373602). Sublethal effects were observed in both studies and included loss of equilibrium, floating at the surface, forward pointing pectoral fins, erratic swimming, labored respiration, quiescence, fish at the bottom of the test chamber, and surfacing.

Chronic Toxicity to Marine-Estuarine Fish

No data are available for the chronic toxicity of terbufos to estuarine/marine fish. Therefore, a NOAEC for estuarine/marine fish of 0.14 µg/L was calculated using the acute toxicity endpoint for sheepshead minnow and an ACR for freshwater fish (i.e., rainbow trout) (see **Table C-1** in **Appendix C** for calculation).

Acute Toxicity to Freshwater Invertebrates

TGAI

Daphnia magna is the most sensitive species tested with acute toxicity ranging from 48 hr LC_{50} = 0.17 to 0.4 µg ai/L (MRID 00101495 and 40098001); the majority of individuals displaying sublethal effects (erratic swimming and lying on the bottom) were deceased by 48 hours. *Gammarus pseudolimnaeus* showed a 96 hr LC_{50} = 0.2 µg ai/L (MRID 40098001). *Chironomus plumosus* showed a 48 hr LC_{50} = 1.4 µg ai/L (MRID 40098001). Crayfish showed a 96 hr LC_{50} = 8 µg ai/L (MRID 00085176); sublethal effects were not reported for surviving individuals.

In addition to the available registrant submitted studies for freshwater invertebrates, two open literature studies were identified in the ECOTOXicology database that reported a more sensitive endpoint. Both studies were classified as qualitative (described below); therefore, the results are not used to calculate RQ values but are incorporated into the risk characterization.

The freshwater invertebrate, *Ceriodaphnia* cf *dubia*, showed a 48 hr EC_{50} = 0.121 to 0.142 µg ai/L and a 96 hr EC_{50} = 0.074 to 0.078 µg ai/L (Choung et al., 2011b). The ranges represent the EC_{50} values from two independent tests. A second set of experiments was conducted that reported only 96 hr EC_{50} values; these values were similar to those from the first set of experiments. Sublethal effects were not reported. The study also reported on toxicity of degradation products (discussed below) and pesticide mixtures (discussed below). The study was classified as qualitative because exposure concentrations were not reported and exposure concentrations were not verified by analytical measurement with exception of the highest test concentration.

Gammarus pseudolimnaeus showed a range of 96 hr LC_{50}s from 0.08 to 1.24 µg ai/L (Howe et al., 1994) based on a range of pH (6.5 – 9.5) and temperature (7 to 17°C) conditions. Toxicity (LC_{50} = 0.17 µg ai/L) was esentially the same as that observed in MRID 40098001 (LC_{50} = 0.20 µg ai/L; 95% confidence interval = 0.1-0.3 µg ai/L) under the same conditions (pH 7.4–7.5 and 17°C). At 96 hr, toxicity tended to increase with increasing temperature and change in pH away from near neutral (i.e., 7.5). However, overall there was not a statistically significant effect of pH on toxicity. Similarly, there was no difference in toxicity at 12 and 17°C; however, toxicity at those temperatures was significantly greater than that at 7°C. Sublethal effects were not reported. The study was classified as qualitative for various reasons including but not limited to questions about control mortality, exposure concentrations were not reported, and exposure concentrations were not verified by analytical measurement with exception of the highest and lowest test concentration at the beginning of the experiment.

End Use Product

The 15% granular formulation of terbufos (Counter 15G) is comparable in acute toxicity to technical grade terbufos. The 48 hr LC_{50} = 0.9 (95% confidence interval of 0.8-1.2) µg ai/L for *Daphnia magna* (MRID FE0TER06). Sublethal effects were not reported.

Chronic Toxicity to Freshwater Invertebrates

A 21-day life cycle study with *Daphnia magna* (MRID 00162525) showed reduced body length and number of offspring at 0.076 µg ai/L, the highest test concentration. The NOAEC = 0.030 µg ai/L. Daphnids, some of which may have later died, were observed lying on the bottom or quiescent toward the end of the experiment (day 19 and 21).

Degradation Products

Several sources of information suggest that terbufos sulfoxide and terbufos sulfoxone are similar to terbufos in their acute toxicity to aquatic invertebrates.

Toxicity studies are not available; however, the registrant submitted information about the toxicity of terbufos sulfone and terbufos sulfoxide to *Daphnia magna* based on a screening study (MRID L000037). The registrant reported a 48 hr EC_{50} = 1 µg ai/L for terbufos sulfone and the 48 hr EC_{50} = 2.1 µg ai/L for terbufos sulfoxide. No sublethal effects were reported. The information is taken at face value and suggests that the degradates are similar to terbufos in acute toxicity.

In addition to the available registrant submitted information, there are two open literature studies that reported toxicity of terbufos sulfoxide and terbufos sulfone in comparison to terbufos. One study reported toxicity to *Ceriodaphnia* cf *dubia* (Choung et al., 2011b; discussed above). Terbufos sulfoxide showed a 48 hr EC_{50} = 0.489 to 0.594 µg ai/L and a 96 hr EC_{50} = 0.360 to 0.363 µg ai/L. Terbufos sulfone showed a 48 hr EC_{50} = 0.324 to 0.381 µg ai/L and a 96 hr EC_{50} = 0.148 to 0.222 µg ai/L. The ranges represent the EC_{50} value from two independent tests. These values are within a factor of 5x of the terbufos toxicity observed in concurrently conducted studies. A second and third set of experiments were conducted that reported only 96 hr EC_{50} values; these values were similar to those from the first set of experiments. No sublethal effects were reported.

The second study reported toxicity to *Chironomus tepperi* (Choung et al., 2010). There was not a statistically significant difference in the toxicity of terbufos, terbufos sulfoxide, and terbufos sulfone. Toxicity of the three compounds differed less than a factor of 2x. Terbufos showed a 96 hr EC_{50} = 1.99 to 2.27 µg ai/L, terbufos sulfoxide showed a 96 hr EC_{50} = 3.53 to 3.74 µg ai/L, and terbufos sulfone showed a 96 hr EC_{50} = 2.49 to 2.69 µg ai/L. The ranges represent the EC_{50} value from two independent tests. A second set of experiments was conducted that reported 96 hr EC_{50} values that were similar to those from the first set of experiments. No sublethal effects were reported.

Acute Toxicity to Marine/Estuarine Invertebrates

In three 96 hr acute toxicity studies with mysid shrimp, the LC_{50} ranged from 0.22 to 0.54 µg ai/L (MRID 00162523, 41297903, and 42306701). The two older studies showed excessive control mortality (more than 10%). One, a static test (MRID 00162523), showed 20% mortality in the negative control but 0% in the solvent control. The other, a flow-through test (MRID 41297903), showed 5% mortality in the negative control but 15% in the solvent control (the study author indicated that dead organisms were not located and suggested that the loss was due to misplacement of organisms during transfer between vessels at test initiation). Although the control mortality raises questions about the toxicity values of the older studies, the three studies show consistent results under different exposure conditions (static vs. flow-through) with LC_{50} values differing by only 2.5X. Sublethal effects included quiescence, lying on the bottom, surfacing, loss of equilibrium, erratic swimming, gyrating motions, and lethargy.

Eastern oyster (*Crassostrea virginica*) showed a 96 hr EC_{50} = 201 µg ai/L (MRID 42381501).

Chronic Toxicity to Marine-Estuarine Invertebrates

No data are available for the chronic toxicity of terbufos to estuarine/marine invertebrates. Therefore, a chronic toxicity endpoint for estuarine/marine invertebrates of 0.041 µg/L was calculated using the acute toxicity endpoint for mysid shrimp and an ACR for freshwater invertebrates (i.e., *Daphnia magna*) (see **Table C-1** in **Appendix C** for calculation).

Aquatic Plants

Two toxicity studies are available for non-vascular plants. A study with a freshwater green algae showed a 96 hr EC_{50} >1.85 mg ai/L (MRID 48689902). The NOAEC = 0.399 mg ai/L and the LOAEC = 1.00 mg ai/L based on reduced cell density, area under the growth curve, average specific growth rate, and yield. A study with a marine diatom showed a 96 hr EC_{50} >1.01 mg ai/L and the NOAEC ≥ 1.01 mg ai/L (MRID 48939101). Statistically significant adverse effects were not observed in this study. Although this study had guideline deviations that likely confounded the results (*e.g.*, excessive variation in initial cell density), the study is sufficient to indicate that there is likely no inhibition within the range of concentrations tested. Data are not available for freshwater diatom or bluegreen algae species.

In addition to the available registrant submitted studies for non-vascular aquatic plants, an open literature study (Tien and Chen, 2012) was identified in the ECOTOXicology database that reported a more sensitive endpoint for non-vascular aquatic plants. The freshwater diatom, *Nitzschia* sp, showed a 96 hr EC_{50} = 0.59 to 1.51 mg ai/L. Two other test species showed less sensitivity: *Oscillatoria* sp. (96 hr EC_{50} = 7.99 mg ai/L) and *Chlorella* sp. (96 hr EC_{50} = 41.16 mg ai/L). The study was classified as qualitative in part because of a lack of information about growth in the controls. Therefore, the results are not used to calculate RQ values, but are incorporated into the risk characterization.

A vascular plant study with duckweed showed an EC_{50} > 4.20 mg ai/L (MRID 48689901). The NOAEC = 0.280 mg ai/L and the LOAEC = 0.630 mg ai/L based on frond number, growth rate of frond number, and yield of frond number. Inhibition was observed at higher concentrations for area under the curve and biomass.

4.2 Terrestrial Organisms

Acute Oral Toxicity to Birds

TGAI

The acute oral LD_{50} = 28.6 (22.2-55.9; 95% confidence interval) mg ai/kg bw for bobwhite quail (MRID 00106551) when exposed to the TGAI. Observed sublethal effects included lethargy progressing to depression, reduced reaction to external stimuli, loss of coordination, lower limb weakness, prostrate posture, loss of righting reflex, salivation, and lower limb rigidity.

Three open literature studies identified in the ECOTOXicology database reported a more sensitive endpoint. Bobwhite quail showed acute oral toxicity ranging from an LD_{50} = 15 (95% confidence interval = 12-19 and slope = 7.9) (Hill and Camardese, 1984) to 24.4 (95% confidence interval = 18.1-31.8 and slope = 5.1) mg ai/kg bw (Brewer et al., 1996). Observed sublethal effects reported by Brewer et al. (1996) were consistent with those reported in other studies: all dosed birds exhibited lethargy, wing droop, piloerection and diarrhea whereas birds receiving higher doses were ataxic and prostrate prior to death. Wolfe and Kendall (1998) examined toxicity of different age classes of red-winged blackbirds and starling; in general both species showed increasing LD_{50}s with increasing age. Adult red-winged blackbirds showed an LD_{50} = 2.06 (95% confidence interval = 1.52-3.53) mg ai/kg bw and nestlings (0-11 days old) showed sensitivity ranging from an LD_{50} = 0.36 to 3.33 mg ai/kg bw. Starlings were less sensitive: adults showed an LD_{50} = 204 (95% confidence interval = 130-350) mg ai/kg bw and nestlings (0-19 days old) showed sensitivity ranging from an LD_{50} = 2.3 to 60.8 mg ai/kg bw. Red-winged blackbird nestlings showed behaviors such as failure to beg, vocalize, and respond to parental stimulation and some of those birds were thrown out of the nest. The study also reported reduced plasma and brain cholinesterase activity from exposure to terbufos. The three open literature studies were classified as qualitative for various reasons including but not limited to: (a) a general lack of details about experimental design (Brewer et al., 1996), (b) limited dose levels were tested for red-winged blackbirds, dose levels were not reported (range only) or verified by analytical measurement, and there was a loss of birds due to illness or escape at dosing (Wolfe and Kendall, 1998), and (c) dose levels were not reported or verified by analytical measurement (Hill and Camardese, 1984). Therefore, results are not used to calculate RQ values but are incorporated into the risk characterization.

End Use Product

Results for formulated product testing also show that terbufos is highly toxic to birds on an acute oral basis (MRID 40660705, 40660706, 40660707, 40660708, 41508802, 41508803, 41508804, and 41508805). The product Counter 15G showed an LD_{50} = 43.5-44.3 mg ai/kg bw (290-295 mg formulation/kg bw)[1] for bobwhite quail, an LD_{50} =13.2 mg ai/kg bw (88 mg formulation/kg bw) for mallard duck, and an LD_{50} = 22.2 mg ai/kg bw (148 mg formulation/kg bw) for brown-headed cowbird. Although greater sensitivity was not observed (TGAI vs TEP tested in the same study), it is noted that Hill and Camardese (1984), as discussed above, tested bobwhite quail with Counter 15G and showed an LD_{50} = 26 mg ai/kg bw. The product Counter CR showed an LD_{50}

[1] Range based on two studies.

= 47.6 mg ai/kg bw (238 mg formulation/kg bw) for bobwhite quail and an LD_{50} = 16.9 mg ai/kg bw (85 mg formulation/kg bw) for brown-headed cowbird. The product Counter 20P showed an LD_{50} = 50 mg ai/kg bw (250 mg formulation/kg bw) for bobwhite quail and an LD_{50} = 32.2 mg ai/kg bw (161 mg formulation/kg bw) for mallard duck. Sublethal effects observed in these studies are consistent with those observed in response to oral dosing with the TGAI (see **Appendix C** for details by study).

Acute Dietary Toxicity to Birds

Bobwhite quail is the most sensitive species tested on an acute dietary basis with an LC_{50} = 143 (125-201; 95% confidence interval) ppm ai (MRID 00087717) and 157 ppm ai (103-214; 95% confidence interval) ppm ai (MRID 00160387) – both based on nominal test concentration. Bobwhite quail showed decreased locomotor activity, feather erection, loss of righting reflex, depression (lethargy), reduced reaction to sound and movement, wing droop, loss of coordination, prostrate posture, lower limb rigidity, ruffled appearance, lower limb weakness, reduced body weight gain, and reduced food consumption.

Mallard duck was tested on an acute dietary basis and showed an LC_{50} = 153 (117-198; 95% confidence interval) ppm ai (MRID 00087717) and 697 ppm ai (584-1616; 95% confidence interval) ppm ai (MRID 00035120) – both based on nominal test concentrations. Mallard ducks showed decreased locomotor activity, feather erection, loss of righting reflex, reduced body weight, and reduced food consumption.

Chronic Toxicity to Birds

Available studies do not clearly define a NOAEC. Studies with bobwhite quail and mallard duck (MRID 00097892 and 00085177) showed possible effects on viable embryos of eggs set at 2 ppm ai. Mallard duck also showed decreasing body weight at both 2 and 20 ppm ai throughout the study in contrast to the control birds, which gained weight. However, the results of these studies cannot be confirmed due to a lack of pen by pen data.

A second study with mallard duck showed a possible NOAEC = 5 ppm ai based on an effect (not statistically significant) on embryo viability at 15 ppm ai (MRID 0161574). A second study with bobwhite quail showed no effects at 30 ppm ai, the highest test concentration tested (MRID 00161573).

Phorate, the closest chemical analog to terbufos, showed a NOAEC = 5 ppm ai for mallard duck (MRID 00158334). The subacute dietary toxicity of phorate to mallard duck (LC_{50} = 240 ppm ai, MRID 00022923) is also similar to the toxicity of terbufos. Given that a NOAEC is not clearly defined for terbufos, an approximate NOAEC of 5 ppm ai is assumed based on the combined information from the available terbufos and phorate studies. Risk conclusions would not change if the NOAEC was lower than 2 ppm ai as suggested by the study results that could not be confirmed (MRID 0097892 and 00085177).

Acute Oral Toxicity to Mammals

TGAI

The acute oral LD_{50} = 1.25 (0.98-1.52; 95% confidence interval) mg ai/kg bw for female rats (MRID 44021601) when exposed to the TGAI. Observed sublethal effects included tremors, salvation, exophthalmos (bulging of the eye), and decreased activity. All survivors appeared normal 9 days after dosing.

End Use Product

Results for formulated product testing also show that terbufos is very highly toxic to mammals on an acute oral basis (MIRD 47512801) and that the 20G formulation is slightly more toxic than the TGAI. The product Counter 20G showed an LD_{50} = 0.836 mg ai/kg bw for female rats (confidence intervals could not be calculated).

Chronic Toxicity to Mammals

A 2-generatation reproduction study with rats showed a NOAEC(L) = 1 ppm ai (0.07-0.09 mg ai/kg bw/day) for maternal/offspring and reproductive effects (MRID 43649402). The LOAEC(L) = 2.5 ppm ai (0.18-0.24 mg ai/kg bw/day) based on decreased pregnancy rate, decreased male fertility, decreased body weight gain in adult females during lactation, and decreased pup weights. Cholinesterase inhibition was observed at 1 ppm ai and higher (NOAEC = 0.5 ppm ai).

Terrestrial Invertebrates

The acute contact LD_{50} = 4.09 μg ai/bee when exposed to the TGAI (MRID 00066220). Acute and chronic oral toxicity data (adult or larvae) are not available for terbufos or phorate, the structural analog of terbufos.

Terrestrial plants

In a Tier I seedling emergence study, no statistically significant inhibition was observed in any of the ten tested species (MRID 48710801). The EC_{25} > 2.04 lb ai/A and the NOAEC = 2.04 lb ai/A for both monocots and dicots. A vegetative vigor study is not available.

The majority of open literature studies show no effects to terrestrial plants at the tested concentrations. However, a small number show phytotoxicity effects (other than growth or survival) or reduced yield in field studies that may indicate greater sensitivity than registrant submitted data; thus, these studies are discussed qualitatively in the risk characterization. Greenhouse grown corn treated at both 0.98 and 1.96 lb ai/A showed increased chlorosis (7 day old corn) and decreased tissue zinc concentration (at harvest); a NOAEC was not reported for these endpoints (Matocha and Hopper, 2001). Testing was conducted on 15G and CR formulations. Reduced chlorophyll (28 day old corn; 15G only) and plant height (7 day old corn) were observed for both test concentrations early in the experiment; however, both variables showed recovery compared to the control at time points thereafter. Two field studies showed effects of terbufos on plant yield (reduced numbers of sugar beet plants at 1.78 lb ai/A; Downard et al., 1999 and kenaf plants at 2 lb ai/A; Barillas-Argueta, 1993); however, the observed effects were isolated and there is inherent uncertainty as to the cause of effects in field studies. Yield was only impacted in a single instance in either study (single year and location); kenaf was tested in two years at a single location and sugar beet was tested in two years at three different locations. In addition, Downard et al. (1999) tested both 15G and CR formulations at each location/year except the single instance that showed reduced yield. In that case, the test material was only reported as "terbufos". There were no additional effects on kenaf (plant diameter, height, and weight; Barillas-Argueta, 1993) or sugar beet (injury index, root yield, and sucrose characteristics; Downard et al, 1999).

4.3 Simulated and/or Actual Field Tests

Several field studies provide information on impacts to non-target organisms following application of terbufos. Among the limitations of field studies is the issue with false negatives (i.e., the failure to identify animals impacted by exposure to terbufos). This is in part because findings are highly dependent upon the probability of locating a dead animal on the treated field, the probability of locating a dead animal before it is removed from the treated field by a scavenger, and the probability that a moribund animal moved off the treated field by itself.

1. *Terrestrial Field Study*. Counter 15G applied to corn fields at 1 lb ai/A at time of plant showed minimal acute effects on wildlife (two dead birds); however carcass searches, residue analyses, and miscellaneous wildlife observations were very limited (MRID 00085178, 00085180, and 00087726).

2. *Simulated Field Study, exposure to treated soil*. Ring-necked pheasants were exposed to soil treated with Counter 15G at a rate equivalent to 1 to 5 lb ai/A and residues were not detected in soil 22 days after the initial exposure. No poisoning symptoms were observed during 55 days of observation following treatment. Two of three birds exposed to a simulated spill died within 12 hours of the initial exposure (MRID 00085179, 00085183, and FEOTEROl).

3. *Terrestrial Field Study*. Terbufos was applied at planting at 2.6 lb ai/A and 10 weeks later as a broadcast aerial application at 1 lb ai/A to a cornfield in Maryland. Following the at-planting application, several species of wildlife were observed dead (one bluebird, one morning dove, two snakes, and one turtle) or alive and exhibiting signs of cholinergic poisoning (one blue jay, one robin, and one brown-headed cowbird). The affected blue jay and dead bluebird contained residues of 0.24 and 0.15 ppm, respectively. Seven feather spots were also found indicating a dead bird that was consumed by a predator. Following the aerial application, surveys identified eight dead birds, one affected bird, 14 dead mammals (mouse, rat, woodchuck, shrew, raccoon, and rabbit), one dead reptile, six feather spots, one fur spot, and several dead fish. Detectable levels of terbufos residues in the affected and dead animals ranged from 0.09 to 8.47 ppm (MRID BAOTEROl and 145854).

4. *Terrestrial Field Study*. Three seasons of field research were conducted from 1987 to 1989 in south central Iowa to assess the environmental exposure of terbufos and its effects on wildlife in a corn agro-ecosystem. Terbufos was applied at 1.3 lb ai/A in bands and in furrows at the time of

planting of corn. Monitoring and biochemical sampling techniques showed relatively low exposure to most species sampled. Nonetheless, mortalities were observed and individuals showed reduced brain ChE activity and the presence of terbufos residues (including degradation products) in the GI tract. Results from starling nest box monitoring in the second year suggest some effects in reproduction parameters and third year passerine blood plasma ChE activity showed a significant difference between in-furrow treatment sites and controls in blue jay (MRID 40985501 and 41475801).

5. *Simulated Field Study.* A study was conducted to compare the effects of Counter 15G to Counter CR on bobwhite quail and brown-headed cowbirds. Terbufos was applied at time of corn planting in pens using band and in-furrow applications. Despite study limitations, the results suggest that both formulations could impact non-target wildlife species. All treatment pens showed higher mortality rates than controls (MRID 41508801 and 41849201).

4.4 Toxicity of Mixtures

There are not any terbufos products formulated with another active ingredient. However, numerous studies were identified in the open literature that examined the toxicity of terbufos combined with at least one other pesticide (see **Appendix D**). The majority of these studies compared the effects of pesticide mixtures on terrestrial plants, typically corn. These experiments compared toxic effects when terbufos was applied alone to toxic effects when terbufos was applied along with common herbicides to determine if the interaction was neutral, increased toxicity (i.e., additive or synergistic effect) or decreased toxicity (antagonistic effect). It is well established that terbufos and other OP insecticides can have a synergistic interaction with acetolactate synthase (ALS) inhibitor herbicides such as sulfonylureas. The majority of the reviewed studies showed that combined exposure of terbufos and ALS inhibitor herbicides (*e.g.*, nicosulfuron, primisulfuron, rimsulfuron, prosulfuron, chlorimuron, and flumetsulam) increased toxicity to plants; however, terbufos did not increase toxicity of all ALS herbicides (*e.g.* imazaquin) under experimental conditions. Likewise, terbufos interacted with other types of herbicides including photosynthesis inhibitors, growth regulators, shoot and root growth inhibitors, and PPO inhibitors to increase toxicity of some herbicides (*e.g.*, metribuzin, cycloate, and oryzalin) but not others (*e.g.*, atrazine, clopyralid, 2,4-D, metolachlor, alachlor, and acifluorfen). In general, many factors impacted the effects of terbufos-herbicide mixtures including but not limited to the presence of safeners, application rate, application timing, terbufos formulation and method of application, effect endpoint, and experimental site location.

A smaller number of studies tested the effects of mixtures on aquatic organisms. Increased toxicity to fish was observed from exposure to mixtures of terbufos with either permethrin or atrazine. Mixtures of atrazine and terbufos increased the toxicity of terbufos to one aquatic invertebrate species (*Ceriodaphnia dubia*) but not another (*Chironomus tepperi*). The toxicity of terbufos sulfone and terbufos sulfoxide to aquatic invertebrates was not impacted by mixtures with atrazine. Similarly, there was no evidence of synergism when frogs were exposed to a mixture of terbufos sulfone and atrazine. Finally, mixtures of terbufos and other organophosphate chemicals (chlorpyrifos and methamidophos) showed antagonistic interactions on toxicity (decreased) to individual species (*Oscillatoria* sp. and *Chlorella* sp.) and multi species assemblages of algae. In contrast, terbufos and methamidophos may have had a synergistic interaction on the toxicity to the multi species assemblage.

4.5 Incident Information

The RED (USEPA, 1999) reported that terbufos was the leading cause of fish kill incidents reported to EPA for any pesticide applied to corn and ranked fourth in fish kill incidents reported to EPA for any pesticide applied to any crop. Additional terbufos related incidents were obtained from the Ecological Incident Information System (EIIS, v 2.1.1), the Aggregate Incident Data System, and the Avian Incident Monitoring System (AIMS)[2] on May 19, 2014[3]. Incidents occurring after 1999 are typical of those previously reported. There is not enough information provided in the incident reports to determine which if any aquatic incidents reported after 1999 reflect mitigation efforts resulting from the RED. The reports indicate that some incidents prior to 1999 occurred despite the use of buffer strips, which were not required at that time. After 1999, there were four reported incidents with fish, two with birds, and one with mammals in the EIIS database. Two plant damage incidents are reported in the EIIS database; however, in both cases two herbicides were applied in addition to terbufos. Previous assessments of terbufos incidents did not include those identified in the Aggregate Incident Data System or AIMS. Both of these databases revealed incidents prior to and after the RED. Focusing on incidents since the RED, there were five minor wildlife incidents, three bird incidents (not included in EIIS), and six minor plant incidents. Unlike the EIIS database, few details are reported about incidents in the other two databases.

The majority of reported fish incidents occurred prior to the RED. There are several key points about the aquatic incidents reported in the EIIS database:

- The majority of incidents are associated with use on corn.
- Incidents are associated with various methods of application and two of the three granular formulations (Counter 15G and Counter CR). No incidents have been reported for 20G, which was registered more recently.
- The majority of incidents occurred in 5 corn belt states (IA, IN, IL, NE, OH).
- Incidents involve mortality from 20 to 90,000 fish.
- Large grassy buffer strips (300-1000 ft) did not prevent incidents in some cases.
- Incidents generally occurred 2 days to 3 weeks after application.
- In some of the incidents, rainfall was reported as occurring over a period of days to weeks prior to the incident. Based on the limited weather information provided, the Agency believes the incidents could be associated with normal spring rain events, as opposed to unusually severe rainfall events over a short period of time.

The updated incident list is provided in **Appendix E**.

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[2] http://www.abcbirds.org/abcprograms/policy/toxins/aims/aims/index.cfm

[3] It was confirmed that no additional incidents were added to the EIIS or the Aggregate Incident databases between May 19, 2014 and August 25, 2015. The AIMS database was not accessible on August 25, 2015.

V. Aquatic LOC Assessment

5.1 Exposure Estimates

The Surface Water Concentration Calculator (SWCC v 1.106) model[4] was used to generate estimated environmental concentrations (EECs) for the Tier II aquatic exposure assessment. The SWCC is a graphical user interface that runs the Pesticide Root Zone Model (PRZM, v 5, November 15, 2006) and the Variable Volume Water Body Model (VVWM, 3/6/2014) (USEPA, 2006b). Simulations are run for multiple (usually 30) years and the EECs represent peak values that are expected once every ten years based on the thirty years of daily values generated during the simulation. Separate EECs were generated for residues of concern: terbufos, terbufos sulfone, and terbufos sulfoxide. The SWCC model was parameterized using relevant use and environmental fate data for terbufos, terbufos sulfone, and terbufos sulfoxide according to the EFED input parameter guidance for water modeling (USEPA, 2009). Application rates for terbufos sulfone and terbufos sulfoxide were determined by adjusting the application rate of terbufos by the maximum percentage of degradate formed and the molecular weight ratio of terbufos to the degradate. The residue summation method (USEPA, 2008a) was used to estimate the 1-in-10 year exposure concentrations for total toxic residues (TTRs) representing the combined exposure to the residues of concern (terbufos, terbufos sulfone, and terbufos sulfoxide). EXCEL was used to post-process estimated EECs generated for terbufos, terbufos sulfone, and terbufos sulfoxide. One inch incorporation of granular terbufos was modeled to represent the typical incorporation depth for all labeled application methods (in furrow, banded, and knifed-in).

Current terbufos labels require certain setback distances or vegetative buffers between treated areas and surface water. A well maintained vegetative buffer could potentially intercept sediment laden with terbufos via runoff from a treated field. However, the current surface water model does not have the capability to account for the prescribed setbacks or vegetative buffer distances; thus, the SWCC model generated EECs are considered upper bound aquatic exposures. While there is good evidence that buffers can reduce pesticide movement into water bodies to some extent, there is still a great deal of uncertainty regarding the performance of buffers, which includes but is not limited to proper design and placement and the duration of their efficacy. Many studies have been conducted to document the effectiveness of various types of vegetative buffers, commonly known as vegetative filter strips (VFS). Based on a review of available research, EFED hypothesized that the use of VFS may reduce loading of total toxic residues of terbufos in aquatic systems by 50% to 90% (*see* USEPA, 2015 for a full discussion).

Input parameters and representative results of SWCC modeling are provided in **Appendix F**. The highest and lowest EECs based on TTR for various scenarios and application rates are provided in **Table 5**.

[4] http://www.epa.gov/oppefed1/models/water

Table 5. Estimated Environmental Concentrations (EECs) of Total Toxic Residues of Terbufos (TTR[1,2]) for Surface Water and Benthic Layer Based on Selected Crop Scenarios

Use Scenario (modeled rate)	Application Method	Peak EEC (µg/L)[3]	21-DayEEC (µg/L)[3]	60-Day EEC (µg/L)[3]
TTR in Surface Water				
Corn: MScorn_STD ORsweetcorn_OP (1 app. X 1.30 lb ai/acre)	Ground (Incorporated)	23.40 5.52	17.00 4.95	15.50 3.63
Corn: NCcornW_OP NCcornE_STD (1 app. X 2.6 lb ai/acre)		24.80 15.50	21.40 11.30	18.70 9.08
Sugar beet: MNsugarbeet_STD CAsugarbeetWirrg_OP (1 app. X 1.96 lb ai/acre)		14.20 9.84	8.03 8.27	6.30 6.89
Sorghum: TXsorghum_OP KSsorghum_STD (1app. X 1.695 lb ai/acre)		35.70 12.30	21.90 9.83	18.50 8.30
TTR in Benthic Layer (Pore Water)				
Corn: MScorn_STD ORsweetcorn_OP (1 app. X 1.30 lb ai/acre)	Ground (Incorporated)	17.60 2.37	16.80 2.31	--
Corn: NCcornW_OP NCcornE_STD (1 app. X 2.6 lb ai/acre)		11.20 6.04	11.20 5.67	--
Sugar beet: MNsugarbeet_STD CAsugarbeetWirrg_OP (1 app. X 1.96 lb ai/acre)		4.91 4.25	4.89 4.23	--
Sorghum: TX sorghum_OP KS sorghum_STD (1app. X 1.695 lb ai/acre)		12.50 5.88	11.40 5.86	--

[1] Terbufos plus its major degradates, terbufos sulfone and terbufos sulfoxide.
[2] EECs do not account for required vegetative buffers and setback distances.
[3] SWCC modeled values are the highest and lowest TTR EECs for each crop and application rate.

5.2 RQ Values

Acute and chronic LOCs for fish and invertebrates are exceeded for use of terbufos on corn, sorghum, and sugar beet (**Table 6**). A range of RQs was presented for each use representing the use scenario resulting in the lowest and highest EECs. Acute RQs for fish range from 3-46 and chronic RQs for fish range from 26-187. Acute RQs for aquatic invertebrates range from 11-210 and chronic RQs for aquatic invertebrates range from 56-730. The listed species LOC (1) is not exceeded for aquatic plants (vascular or non-vascular).

Table 6. Aquatic RQs for Use of Terbufos[1,2,3,4,5]

Taxonomic Group		Crop (application rate)			
		Corn (1.3 lb ai/A)	NC Corn (2.6 lb ai/A)	Sugar Beet (1.96 lb ai/A)	Sorghum (1.695 lb ai/A)
Freshwater Animals	Fish (acute)	**7-30**	**20-32**	**13-18**	**16-46**
	Fish (chronic)	**36-155**	**91-187**	**63-69**	**83-185**
	Invertebrate (acute)	**33-138**	**91-146**	**58-84**	**72-210**
	Invertebrate (chronic)	**165-567**	**377-713**	**268-276**	**328-730**
	Benthic Invertebrate (acute)	**14-104**	**36-66**	**25-29**	**35-74**
	Benthic Invertebrate (chronic)	**77-560**	**189-373**	**141-163**	**195-380**
Marine/ Estuarine Animals	Fish (acute)	**3-15**	**10-16**	**6-9**	**8-22**
	Fish (chronic)	**26-111**	**65-134**	**45-49**	**59-132**
	Invertebrate (acute)	**25-106**	**70-113**	**45-65**	**56-162**
	Invertebrate (chronic)	**121-415**	**276-522**	**196-202**	**240-534**
	Benthic Invertebrate (acute)	**11-80**	**27-51**	**19-22**	**27-57**
	Benthic Invertebrate (chronic)	**56-410**	**138-273**	**104-119**	**143-278**
Algae (listed species)[6]		0.01-0.06	0.04-0.10	0.02-0.04	0.03-0.09
Aquatic Vascular plants (listed species)[6]		0.02-0.08	0.06-0.10	0.04-0.05	0.04-0.13

[1] EECs do not account for required vegetative buffers and setback distances.
[2] Range is based on use scenarios resulting in the lowest and highest EECs for each crop as provided in **Table 5**. For example, the acute fish RQ range for corn (1.3 lb ai/A) is based on the peak EEC from the ORsweetcorn_OP scenario (5.52 µg/L) and MScorn_STD (23.40 µg/L).
[3] Acute RQs were calculated using the peak EEC, chronic fish RQs were calculated using the 60-day EEC, and chronic invertebrate RQs were calculated using the 21-day EEC. Benthic invertebrate EECs were calculated using porewater EECs.
[4] RQs were calculated using toxicity endpoints presented in **Table 4**. The listed species RQ for aquatic plants is based on the NOAEC value. Waterflea and Mysid shrimp data were used to calculate RQs for benthic invertebrates because those were the most sensitive invertebrate species and the available data for benthic invertebrates were based on water column concentrations (not spiked sediment).
[5] RQs greater than 1 are rounded to the nearest whole number.
[6] RQs were not calculated for non-listed species because RQs for listed species do not exceed the LOC of 1.0.
BOLD indicates that the RQ is greater than or equal to the LOC for aquatic animals (acute listed species LOC = 0.05 or the chronic LOC = 1.0) or aquatic plants (listed species LOC = 1.0).

5.3 Monitoring Data

The occurrence of terbufos in surface water and groundwater was summarized in the IRED (USEPA, 2001). For surface water, a total of 5198 samples from the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) database were analyzed for terbufos. Terbufos was detected in 17 surface water samples with concentrations ranging from 0.02 to 0.56 µg/L. Terbufos groundwater monitoring information was available from several sources including the registrant, NAWQA, states, and EPA's Pesticides in Groundwater Database. These data represent 4,563 samples from 13 states; of these there were 20 detections of terbufos that ranged from 0.011 to 20.0 µg/L. Terbufos degradates were not included as analytes for surface water or groundwater monitoring.

A surface water and groundwater monitoring study (MRID 46873301) was conducted for terbufos, terbufos sulfone, and terbufos sulfoxide by the registrant. The study was required by the terbufos IRED (USPEA, 2001) to confirm concentrations of terbufos, terbufos sulfone, and terbufos sulfoxide in drinking water sources. The Agency review of this study (USEPA, 2008b) is summarized as follows. For the surface water, a total of 502 samples were collected from 33 sites between 1999 and 2005. For the groundwater, 73 samples were collected from 2003 to 2005. From 1999 to 2003, samples from numerous watersheds were provided by the NAWQA program. In surface water, terbufos and terbufos oxon were not detected above the reporting limits in any samples. Terbufos sulfoxide was detected in four samples at 0.092 to 0.205 µg/L, with an additional nine estimated detections of 0.045 to 0.262 µg/L. Terbufos sulfone was detected in six samples at 0.046 to 0.114 µg/L, with 30 additional estimated detections of 0.012 to 0.034 µg/L. There were no detections of terbufos or any degradates in any of the groundwater samples.

USGS-NAWQA monitoring data from 2006 to the present were accessed on March 18, 2014 to evaluate the post-IRED trend of terbufos, terbufos sulfone, and terbufos sulfoxide concentrations in surface water and groundwater. This dataset included filtered surface water and groundwater monitoring data that were not available in a previously reviewed 2008 monitoring study of terbufos and its degradates in drinking water (USEPA, 2008b). For surface water, a total of 6740 water samples were analyzed for terbufos. Terbufos was detected in only one sample and the concentration was 0.02 µg/L. There were two detections of 0.07 µg/L and 0.17 µg/L terbufos sulfone out of 6198 surface water samples. For groundwater, a total of 3582 water samples were analyzed for terbufos. Terbufos was detected in one sample with a concentration of 0.01 µg/L. There were no detections of terbufos sulfone in any of the groundwater samples.

Post-IRED detections and concentrations of terbufos in surface water and groundwater samples are lower than the pre-IRED monitoring data. The Agency implemented several mitigation and risk management measures necessary to address human health and environmental risks associated with the uses of terbufos during the IRED process. In particular, the application rate for sorghum was reduced from 1.96 lb ai/A to 1.696 lb ai/A and a vegetative buffer was required between the treated area and surface water bodies to mitigate terbufos exposure in surface water. The reduced rate for sorghum and the implementation of vegetative buffers may have resulted in fewer detections and lower concentrations of terbufos and its degradates in surface water and groundwater.

The NAWQA program recently began monitoring the quality of source water and finished water of aquifers and major rivers used by some of the larger community water systems in the United States (Carter et al., 2010). There were 295 anthropogenic organic compounds (AOCs) including terbufos and terbufos sulfone monitored during 2002–2010 for the Source Water-Quality Assessment (SWQA) studies. The SWQA studies are intended to complement drinking-water monitoring required by Federal, State, and local programs, which focus primarily on post-treatment compliance monitoring. A total of 221 surface water samples were analyzed for terbufos and terbufos sulfone. There were no detections of terbufos or terbufos sulfone in any samples.

Monitoring data for surface water, groundwater, and sediment from the California Department of Pesticide Regulation (CDPR) were searched on March 18, 2014. Terbufos was detected in only one sample and the concentration was 0.04 µg/L out of 2538 surface water samples. There were no detections of terbufos or its degradates in any of the groundwater samples.

There are some limitations with the non-targeted monitoring data cited above. Critical information is not available to determine how well sampling events at the monitoring sites correspond with terbufos applications. The sampling frequency may be sufficient for estimating long-term average concentrations for chronic toxicity endpoints but is inadequate for estimating peak exposures for acute endpoints. The monitoring results can provide a lower bound of anticipated exposures from terbufos residues in water bodies in terbufos use areas.

VI. Terrestrial LOC Assessment

6.1 Birds and Mammals

Dietary Ingestion (granules)

T-REX (Terrestrial Residue Exposure Model, v 1.5.2)[5] was used to estimate avian and mammal dietary exposure to terbufos granules based on the LD_{50}/ft^2 method. Risk was assessed based on toxicity to the TGAI and to formulations when data indicated greater toxicity. Representative model input and output are shown in **Appendix G**.

The acute and chronic LOCs are exceeded for use of terbufos on corn, sorghum, and sugar beet (**Table 7 and 8**). The acute listed and non-listed species LOCs are exceeded for 20g and 100g birds (all uses). RQs are at or exceed the listed species acute LOC (0.1) for birds in the 1000g size class (all uses). RQs exceed the non-listed species acute LOC (0.5) for birds in the 1000g size class for uses with the 15G granule (all NC corn uses and banded uses on corn, sorghum, and sugar beet). All uses exceed the listed and non-listed species acute LOCs for all considered size classes of mammals (15-1000g). The chronic LOC (1) is exceeded for all uses (birds and mammals). Available acute dose-based toxicity data for some granule formulations indicates greater toxicity than the TGAI; thus, RQs are greater when based on granule toxicity. Banded application methods result in higher RQs than in-furrow or knifed-in application methods.

[5] http://www.epa.gov/oppefed1/models/terrestrial

Table 7. Avian RQs for Use of Terbufos[1,2]

Use	Application Method (timing)	lb ai/ 1000 ft row	Product	Band width (in)	Toxicity[3]	RQ (acute dose)[4]			RQ (chronic)[5]
						0.02 kg bird	0.1 kg bird	1 kg bird	
Corn	Banded (at planting)	0.15	15G (NC)	7	TGAI	**42**	**7**	**0.47**	**63**
					15G	**127**	**20**	**1**	N/A
		0.075	CR		TGAI	**21**	**3**	**0.23**	**31**
					CR	**30**	**5**	**0.32**	N/A
			15G		TGAI	**21**	**3**	**0.23**	**31**
					15G	**63**	**10**	**0.69**	N/A
			20G	5	TGAI	**30**	**5**	**0.33**	**44**
				4		**37**	**6**	**0.41**	**55**
	In furrow (at planting)	0.15	15G (NC)	1	TGAI	**20**	**3**	**0.22**	**116**
					15G	**59**	**9**	**0.66**	N/A
		0.075	CR		TGAI	**10**	**2**	**0.11**	**58**
					CR	**14**	**2**	**0.15**	N/A
			15G		TGAI	**10**	**2**	**0.11**	**58**
					15G	**30**	**5**	**0.33**	N/A
			20G		TGAI	**10**	**2**	**0.11**	**58**
	Banded (postemergence and at cultivation)	0.075	CR	7	TGAI	**21**	**3**	**0.23**	**124**
					CR	**30**	**5**	**0.32**	N/A
			15G		TGAI	**21**	**3**	**0.23**	**124**
					15G	**63**	**10**	**0.69**	N/A
			20G		TGAI	**21**	**3**	**0.23**	**124**
Sorghum	Knifed in (at bedding and at planting)	0.065	CR	1	TGAI	**9**	**1**	0.09	**13**
					CR	**12**	**2**	**0.13**	N/A
		0.066	15G		TGAI	**9**	**1**	**0.10**	**13**
					15G	**26**	**4**	**0.30**	N/A
		0.065	20G		TGAI	**9**	**1**	0.09	**13**
	Banded (at planting)	0.065	CR	7	TGAI	**18**	**3**	**0.20**	**27**
					CR	**25**	**4**	**0.28**	N/A
		0.066	15G		TGAI	**18**	**3**	**0.20**	**27**
					15G	**55**	**9**	**0.60**	N/A
		0.065	20G		TGAI	**18**	**3**	**0.20**	**27**
		0.066	15G	5	TGAI	**26**	**4**	**0.29**	**38**
					15G	**77**	**12**	**0.87**	N/A
		0.065	20G		TGAI	**25**	**4**	**0.28**	**38**
Sugar beet	Modified in furrow and knifed in (at planting)	0.075	CR	1	TGAI	**10**	**2**	**0.11**	**15**
					CR	**14**	**2**	**0.15**	N/A
			15G		TGAI	**10**	**2**	**0.11**	**15**
					15G	**30**	**5**	**0.33**	N/A
			20G		TGAI	**10**	**2**	**0.11**	**15**
	Banded (at planting and postemergence)		CR	7	TGAI	**21**	**3**	**0.24**	**32**
					CR	**30**	**5**	**0.34**	N/A
			15G		TGAI	**21**	**3**	**0.24**	**32**
					15G	**64**	**10**	**0.72**	N/A
			20G		TGAI	**21**	**3**	**0.24**	**32**
			CR	5	TGAI	**30**	**5**	**0.33**	**175**
					CR	**42**	**7**	**0.46**	N/A
			15G		TGAI	**30**	**5**	**0.33**	**175**
					15G	**89**	**14**	**0.99**	N/A
			20G		TGAI	**30**	**5**	**0.33**	**175**

[1] Product application methods (timing, lb ai/1000 ft row, band width) were obtained from the most recent product labels.
[2] RQs greater than 1 (acute) or 2 (chronic) are rounded to the nearest whole number.
[3] Acute toxicity based on TGAI, Bobwhite quail LD_{50} = 28.6 mg ai/kg/bw; 15G, Mallard duck LD_{50} = 13.21 mg ai/kg bw; 20CR Cowbird LD_{50} = 16.9 mg ai/kg bw
[4] RQs are based on data from single oral dose toxicity studies. Results from dietary studies can be converted to dose equivalent toxicity values; these values result in RQs (not shown) that are similar to those based on single oral dose toxicity studies. Example conversion for LC_{50} = 143 mg ai/kg diet (MRID 00087717): mg ai/kg bw = (mg ai/kg diet * daily food intake)/kg bw. daily food intake = 0.0582 * bw^0.651 (source: SIP v 1.0 manual). bw = 0.157 kg (source: mean value from MRID 00087717). LD_{50} = 15.8 mg ai/kg bw = (143 mg ai/kg diet * 0.017 kg/day)/0.157 kg bw
[5] The dietary-based chronic toxicity value (NOAEC = 5 mg ai/kg diet; MRID 0161574) was converted to a dose equivalent toxicity value. mg ai/kg bw = (mg ai/kg diet * daily food intake)/kg bw. daily food intake = 0.0582 * bw^0.651 (source: SIP v 1.0 manual). bw = 1.136 kg (source: mean value from MRID 0161574). NOAEL= 0.278 mg ai/kg bw = (5 mg ai/kg diet * 0.0632 kg/day)/1.136 kg bw
BOLD indicates that the RQ is greater than or equal to the acute listed species LOC (0.1) or the chronic LOC (1.0). N/A indicates that chronic toxicity data were not available for the formulation. TGAI = technical grade active ingredient. CR, 15G, and 20G refer to Counter (terbufos) formulations. 15G (NC) = North Carolina special local needs label for 15G.

Table 8. Mammalian RQs for Use of Terbufos[1,2]

Use	Application Method (timing)	lb ai/ 1000 ft row	Product	Band width (in)	Toxicity[3]	RQ (acute dose)			RQ (chronic)
						0.015 kg[4]	0.035 kg[4]	1 kg[4]	
Corn	Banded (at planting)	0.15	15G (NC)	7	TGAI	**422**	**224**	**18**	**249**
		0.075	CR, 15G			**211**	**112**	**9**	**124**
			20G	5	TGAI	**296**	**157**	**13**	**174**
					20G	**440**	**233**	**19**	N/A
				4	TGAI	**370**	**196**	**16**	**218**
					20G	**551**	**292**	**24**	N/A
	In furrow (at planting)	0.15	15G (NC)	1	TGAI	**197**	**104**	**8**	**116**
		0.075	CR, 15G			**99**	**52**	**4**	**58**
			20G			**99**	**52**	**4**	**58**
					20G	**147**	**78**	**6**	N/A
	Banded (postemergence and at cultivation)	0.075	CR, 15G	7	TGAI	**211**	**112**	**9**	**124**
			20G			**211**	**112**	**9**	**124**
					20G	**315**	**167**	**14**	N/A
Sorghum	Knifed in (at bedding and at planting)	0.065	CR	1	TGAI	**85**	**45**	**4**	**50**
		0.066	15G			**86**	**45**	**4**	**50**
		0.065	20G			**85**	**45**	**4**	**50**
					20G	**127**	**67**	**5**	N/A
	Banded (at planting)	0.065	CR	7	TGAI	**182**	**96**	**8**	**107**
		0.066	15G			**184**	**97**	**8**	**108**
		0.065	20G			**182**	**96**	**8**	**107**
					20G	**271**	**144**	**12**	N/A
		0.066	15G	5	TGAI	**257**	**136**	**11**	**151**
		0.065	20G			**255**	**135**	**11**	**150**
					20G	**380**	**201**	**16**	N/A

Use	Application Method (timing)	lb ai/ 1000 ft row	Product	Band width (in)	Toxicity[3]	RQ (acute dose)			RQ (chronic)
						0.015 kg[4]	0.035 kg[4]	1 kg[4]	
Sugar beet	Modified in furrow and knifed in (at planting)	0.075	CR, 15G	1	TGAI	**99**	**52**	**4**	**58**
			20G			**99**	**52**	**4**	**58**
					20G	**148**	**78**	**6**	N/A
	Banded (at planting and postemergence)		CR, 15G	7	TGAI	**212**	**113**	**9**	**125**
			20G			**212**	**113**	**9**	**125**
					20G	**316**	**168**	**14**	N/A
			CR, 15G	5	TGAI	**297**	**157**	**13**	**175**
			20G			**297**	**157**	**13**	**175**
					20G	**443**	**235**	**19**	N/A

[1] Product application methods (timing, lb ai/1000 ft row, band width) were obtained from the most recent product labels.
[2] RQs greater than 1 (acute) or 2 (chronic) are rounded to the nearest whole number.
[3] Acute toxicity based on TGAI, Rat LD_{50} = 1.25 mg ai/kg/bw; 20G, rat LD_{50} = 0.836 mg ai/kg bw. Chronic dose based toxicity based on TGAI, NOAEL = 0.07 mg ai/kg bw.
[4] Mammal body weight
BOLD indicates that the RQ is greater than or equal to the acute listed species LOC (0.1) or the chronic LOC (1.0). N/A indicates that chronic toxicity data were not available for the formulation. TGAI = technical grade active ingredient. CR, 15G, and 20G refer to Counter (terbufos) formulations. 15G (NC) = North Carolina special local needs label for 15G.

Dietary Ingestion (contaminated fish)

KABAM (Kow (based) Aquatic BioAccumulation Model, v 1.0)[6] was used to estimate potential bioaccumulation of terbufos in freshwater aquatic food webs and risk to piscivorus mammals and birds that consume terbufos contaminated fish. The model bases bioaccumulation in the food web on the octanol-water coefficient (Kow) of the chemical and the estimated surface water and pore water concentrations of the chemical. Although terbufos, terbufos sulfoxide, and terbufos sulfone show similar toxicity, risk was assessed based on exposure to terbufos alone because the bioaccumulation potential of terbufos is much greater than that of terbufos sulfoxide and terbufos sulfone (terbufos log Kow = 4.71, terbufos sulfone log Kow = 2.48 (EPISUITE estimate), and terbufos sulfoxide log Kow = 2.21 (EPISUITE estimate)). Bioaccumulation based on TTR EECs and the bioaccumulation potential of terbufos would overestimate bioaccumulation in the food web. The bioaccumulation potential is assumed to be low for terbufos sulfone and terbufos sulfoxide based on their Kow values.

The assessment is based on the assumption that terbufos is not metabolized by aquatic organisms (input parameter km = 0 d^{-1}). The elimination rate constant value (k_T = 0.31 d^{-1}) estimated from the laboratory BCF study is similar to the sum of the KABAM estimated loss rate constants (i.e., $k_2 + k_G$ = 0.36 d^{-1}) based on fish weight and water temperature from the BCF study.[7] The results

[6] http://www.epa.gov/oppefed1/models/water
[7] The estimated loss rate constants (k_2 and k_g) were generated using the KABAM model. All default parameters were used, with two exceptions: (1) the large fish was parameterized to represent the average body weight of the fish in the BCF study (6.4 g) and (2) the average temperature of the study (22 °C) was entered as the model water temperature.

of this comparison indicate that metabolism is not a substantial mechanism of depuration and supports the assumption that km = 0 d^{-1}.

RQs were calculated for the crop scenario resulting in the lowest and highest EECs (21 day averaging period) for each use of terbufos (**Appendix F; Table F-4**); as discussed above, EECs are based on terbufos only. Representative KABAM model results are presented in **Appendix H**.

Results from KABAM indicate a risk concern for piscivorus birds and mammals for use of terbufos (**Table 9**). For mammals, all uses, crop scenarios, mammal size classes, and functional feeding groups exceed the LOC on an acute and chronic basis. For birds, the chronic LOC is exceeded only for the crop scenario resulting in the highest EEC estimates for corn and sorghum. Acute RQs for birds exceed the listed species acute LOC but not the non-listed species LOC and only for smaller birds in two feeding groups (represented by sandpipers and rails) for the crop scenario resulting in the highest EECs for each use of terbufos.

Table 9. Piscivorous Wildlife RQs for Use of Terbufos[1,2]

Crop (application rate)	Wildlife Species	Acute RQ		Chronic RQ	
		Dose Based	Dietary Based	Dose Based	Dietary Based
Corn (1.3 lb ai/A)	*Mammalian*				
	fog/water shrew	0.06-**1**	N/A	**2-31**	0.28-**6**
	rice rat/star-nosed mole	0.08-**2**	N/A	**2-38**	0.28-**6**
	small mink	**0.11-2**	N/A	**3-52**	0.42-**8**
	large mink	**0.12-2**	N/A	**3-57**	0.42-**8**
	small river otter	**0.13-2**	N/A	**3-61**	0.42-**8**
	large river otter	**0.15-3**	N/A	**4-73**	0.47-**9**
	Avian				
	sandpipers	0.01-**0.28**	<0.01-0.04	N/A	<0.1-**1.1**
	cranes	<0.01-0.02	<0.01-0.04	N/A	<0.1-**1.2**
	rails	<0.01-**0.15**	<0.01-0.05	N/A	<0.1-**1.3**
	herons	<0.01-0.03	<0.01-0.05	N/A	<0.1-**1.4**
	small osprey	<0.01-0.04	<0.01-0.06	N/A	<0.1-**1.6**
	white pelican	<0.01-0.02	<0.01-0.06	N/A	<0.1-**1.8**
NC Corn (2.6 lb ai/A)	*Mammalian*				
	fog/water shrew	**0.51-0.52**	N/A	**13**	**2**
	rice rat/star-nosed mole	**0.62-0.65**	N/A	**16**	**2**
	small mink	**0.86-0.89**	N/A	**21-22**	**3-4**
	large mink	**0.95-0.98**	N/A	**24-25**	**3-4**
	small river otter	**1**	N/A	**25-26**	**3-4**
	large river otter	**1**	N/A	**32-34**	**4**
	Avian				
	sandpipers	**0.12**	0.02	N/A	0.46-0.48
	cranes	<0.01	0.02	N/A	0.48-0.50
	rails	0.06	0.02	N/A	0.54-0.56
	herons	0.01	0.02	N/A	0.57-0.59
	small osprey	0.02	0.02	N/A	0.69-0.71
	white pelican	<0.01	0.03	N/A	0.79-0.84

Crop (application rate)	Wildlife Species	Acute RQ		Chronic RQ	
		Dose Based	Dietary Based	Dose Based	Dietary Based
Sugar beet (1.96 lb ai/A)	*Mammalian*				
	fog/water shrew	**0.25-0.28**	N/A	**6-7**	**1.1-1.2**
	rice rat/star-nosed mole	**0.31-0.34**	N/A	**8-9**	**1.1-1.3**
	small mink	**0.42-0.47**	N/A	**11-12**	**1.7-1.9**
	large mink	**0.47-0.52**	N/A	**12-13**	**1.7-1.9**
	small river otter	**0.50-0.56**	N/A	**13-14**	**1.7-1.9**
	large river otter	**0.65-0.69**	N/A	**16-17**	**2**
	Avian				
	sandpipers	0.06	<0.01	N/A	0.23-0.25
	cranes	<0.01	<0.01	N/A	0.24-0.26
	rails	0.03	≤0.01	N/A	0.27-0.30
	herons	<0.01	0.01	N/A	0.28-0.31
	small osprey	≤0.01	0.01	N/A	0.34-0.37
	white pelican	<0.01	0.01	N/A	0.40-0.43
Sorghum (1.695 lb ai/A)	*Mammalian*				
	fog/water shrew	**0.35-0.96**	N/A	**9-24**	**1.5-4**
	rice rat/star-nosed mole	**0.43-1**	N/A	**11-29**	**1.6-4**
	small mink	**0.59-2**	N/A	**15-40**	**2-6**
	large mink	**0.66-2**	N/A	**16-44**	**2-6**
	small river otter	**0.71-2**	N/A	**18-47**	**2-6**
	large river otter	**0.86-2**	N/A	**21-55**	**3-7**
	Avian				
	sandpipers	0.08-**0.22**	0.01-0.03	N/A	0.32-0.86
	cranes	≤0.01	0.01-0.03	N/A	0.34-0.90
	rails	0.04-**0.12**	0.01-0.04	N/A	0.37-**1.0**
	herons	<0.01-0.02	0.01-0.04	N/A	0.40-**1.1**
	small osprey	0.01-0.03	0.02-0.05	N/A	0.48-**1.3**
	white pelican	≤0.01	0.02-0.05	N/A	0.53-**1.4**

[1] Range is based on use scenarios resulting in the lowest and highest terbufos EECs for each crop as provided in **Appendix F, Table F-4**. For example, the RQ range for corn is based on the 21 day EECs (terbufos only) from the ORsweetcorn_OP scenario (0.13 μg/L surface water; 0.34 μg/L pore water) and MScorn_STD (2.44 μg/L surface water; 8.74 μg/L pore water).
[2] RQs greater than 1 (acute) or 2 (chronic) are rounded to the nearest whole number.
BOLD indicates that the RQ is greater than or equal to the acute listed species LOC (0.1) or the chronic LOC (1.0).

Inhalation

The Screening Tool for Inhalation Risk (STIR v1.0)[8] was used to provide an upper bound estimate of bird and mammal exposure to terbufos through vapor inhalation. There is no spray drift exposure (droplet inhalation) because terbufos is applied as a granule. The screening suggests that terbufos use has the potential for significant vapor inhalation risk (the ratio of vapor concentration in the air to the inhalation LD_{50} exceeds the screening threshold of 0.1). Model inputs and output are presented in **Appendix I**.

[8] http://www.epa.gov/oppefed1/models/terrestrial

Drinking Water

The Screening Imbibition Program (SIP v.1.0)[8] was used to calculate an upper bound estimate of bird and mammal exposure to terbufos in drinking water. The screening indicates potential acute and chronic risk to birds and mammals through the consumption of terbufos-contaminated drinking water. Model results are presented in **Appendix J**.

6.2 Terrestrial and Semi-Aquatic Plants

TerrPlant (v 1.2.2)[8] was used to calculate EECs for characterizing exposure to terrestrial and semi-aquatic plants through run-off of terbufos. There is no spray drift exposure because terbufos is applied as a granule. The listed species LOC of 1 is not exceeded for any use. Input and output for the maximum application rate (NC use on corn) are shown in **Appendix K**.

VII. Risk Characterization

7.1 Aquatic Organisms

Aquatic Fish and Invertebrates

The standard modeling approach based on exposure to total toxic residues (terbufos, terbufos sulfoxide, and terbufos sulfone) indicates an acute and chronic risk concern for fish and aquatic invertebrates from use of terbufos on corn, sorghum, and sugar beet (**Table 6**). TTR was used to calculate EECs because terbufos sulfoxide, and terbufos sulfone are more persistent than terbufos and available toxicity data indicate that they are similar in toxicity to terbufos. Concerns about adverse effects to aquatic organisms from terbufos use are strongly supported by widespread fish kill incidents. Aquatic incidents prior to the RED do not necessarily reflect any of the mitigation which now requires implementation of vegetative buffers and setbacks between the treated field and water bodies. Buffers may make aquatic incidents less likely to occur and it is noted that the number of reported fish incidents per year has declined since the RED; however, this does not necessarily indicate a lack of incidents or reduced risk. Reliance on the frequency of incidents may significantly underestimate the extent of the actual impacts. Adverse ecological effects cannot be assumed to be reliably detected and reported. Before an incident can be reported, it must be observed and attributed to terbufos. Reproductive effects or other sublethal effects, effects on eggs or small age classes, or impacts on relatively small species (invertebrates, amphibians, or small fish species) are likely to escape immediate detection. For example, the only invertebrate species cited in terbufos related incidents is crayfish, which is a relatively conspicuous invertebrate. Toxicity data indicate that invertebrates are more sensitive to terbufos than fish; thus, effects on invertebrates can be assumed when fish kill incidents are reported but the absence of fish incidents does not indicate an absence of adverse effects on invertebrates.

In many cases, incident reports for fish kills associated with terbufos use on corn indicate that residues of terbufos, terbufos sulfone, or terbufos sulfoxide were detected at levels in the surface water of static systems that are similar to those predicted by modeling of static water systems (**Appendix E, Table E-1 and Appendix F, Table F-4**). Surface water concentrations observed in the incident reports reflect a wide range of variables including but not limited to application rate and method, time elapsed between application and water sampling, distance of the water body from the application site, and the size of the water body relative to that of the treated field. Monitoring data generally show lower concentrations of terbufos in flowing water systems than predicted through modeling for static water systems, but non-targeted sampling is unlikely to capture peak concentrations (*see* **Section V**). Nonetheless, monitoring information indicates that concentrations of terbufos, terbufos sulfone, and terbufos sulfoxide sometimes reach levels in flowing water systems that would adversely affect aquatic animals. For instance, more recent NAWQA monitoring data show surface water concentrations of terbufos up to 0.02 μg/L and terbufos sulfone concentrations up to 0.17 μg/L, which are high enough to trigger an acute risk concern for aquatic invertebrates.

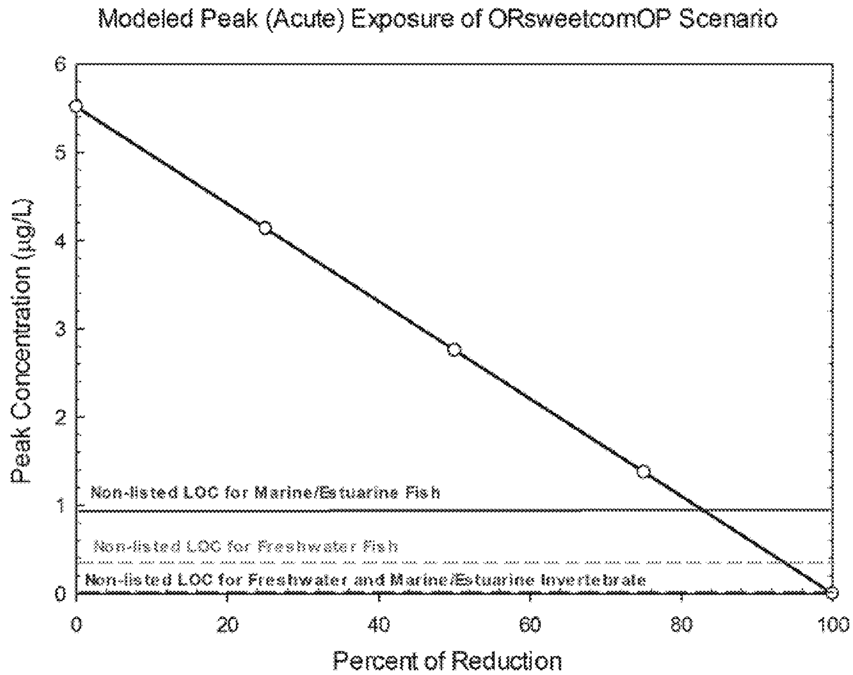
Several open literature studies showed greater acute (freshwater invertebrates) and chronic (freshwater fish) toxicity than demonstrated in registrant submitted studies (discussed in **Section IV**). RQs were not calculated because the studies were classified as qualitative. These data do not change the risk conclusions; however, it does suggest that acute risk to freshwater invertebrates and chronic risk to freshwater fish may be greater than indicated by toxicity based on registrant submitted data.

In addition, one open literature study showed adverse developmental effects on southern bell frogs exposed to 10 μg terbufos sulfone/L for 10 weeks. Assuming that terbufos and terbufos sulfoxide are similar in toxicity to terbufos sulfone as for other taxa, then adverse effects may be reasonably expected to occur given that 60-day TTR surface water EECs range from 3.63 to 18.70 μg/L.

The quantitative risk assessment (i.e., calculation of RQs) is based on upper bound EECs that do not consider the labeled setbacks and vegetative buffers. It is assumed that buffers will reduce loading to aquatic systems due to run-off from treated fields; thus, risk to aquatic organisms may be reduced with use of buffers. Although currently available models cannot account for the impact of vegetative buffers (*see* **Section V** for discussion), the potential impact of buffers is characterized by calculating how effective they would need to be to reduce EECs and thus RQs below LOCs. While there is good evidence that buffers can reduce pesticide movement into water bodies to some extent, there is still a great deal of uncertainty regarding the performance of buffers, which includes but is not limited to proper design and placement and the duration of their efficacy. Based on a review of available research, EFED hypothesized that the use of vegetative buffers may reduce loading of total toxic residues of terbufos in aquatic systems by 50% to 90% (*see* USEPA, 2015 for a full discussion). In comparison, loading would need to be reduced more than about 93% to 99.9% for RQs to be below LOCs, depending on the crop, taxonomic group (fish or invertebrate; freshwater or marine/estuarine species), listed or non-listed species status, and LOC (acute or chronic). There is only one exception that requires loading reductions less than the hypothesized maximum of 90%. A vegetative buffer would need to reduce the "no buffer" EECs by ≥ 85% for the scenario with the lowest surface water EECs (5.52 μg/L; corn; ORsweetcorn_OP scenario) to be below the acute non-listed species LOC for marine/estuarine fish (**Figure 1**). For all other scenarios, loading would need to be reduced more than 90% for the RQ to be below the acute non-listed species LOC for marine/estuarine fish. Overall, available information suggests that loading may be reduced up to

90% with the use of vegetative buffers; however, the overall risk concerns for fish and aquatic invertebrates remain because RQs remain above the LOCs after accounting for those reductions.

Figure 1.



Aquatic plants

The LOC (1.0) is not exceeded for listed aquatic plants (RQs ≤ 0.13) from any labeled use. Although EC_{50}s were not established in the available studies, there is not a risk concern for non-listed plants given that there is not a risk concern for listed plants. Although there is open literature data for a freshwater diatom (*Nitzschia* sp.) that showed a more sensitive EC_{50} value than registrant submitted data, the reported EC_{50} value is higher than the NOAEC values in the registrant submitted data which did not trigger a risk concern for listed species. Although the NOAEC was not reported, there is little uncertainty in the risk conclusions of this assessment because there are not currently any listed algal species. That same study also tested two other algal species that showed less sensitivity to terbufos. Based on the weight of the available evidence, there is not a risk concern for aquatic vascular or non-vascular plants.

7.2 Terrestrial Organisms

Birds and Mammals

There are several potential sources of terbufos exposure to birds and mammals. Granules may be ingested directly by birds foraging for seed and grit at or below the soil surface on treated areas. The similarity of the granules to natural forage or grit has been suggested as an important characteristic which may influence ingestion of granules. Grit preferences are expected to vary among avian species and may depend on variables including size, shape, texture, and color. Birds and mammals may also ingest granules adhered to the surface of invertebrate prey items such as earthworms and grubs or accidentally ingest granules when foraging for seeds and insects. Piscivorous birds and mammals may be exposed to terbufos residues in contaminated fish. Other routes of exposure for both birds and mammals include ingestion of contaminated drinking water, vapor inhalation, and dermal exposure through contact with treated soil. The weight of evidence from the assessment of various pathways supports an acute and chronic risk concern for birds and mammals from labeled uses of terbufos.

The standard modeling scenario for consumption of granules (LD_{50}/ft^2 method) indicates an acute and chronic risk concern for evaluated size classes of birds and mammals for use on corn, sorghum, and sugar beet (**Table 7** and **8**). While the LD_{50}/ft^2 method has no ecological meaning, it is used as a means to characterize the level of exposure in a relatively small foraging area; therefore, the likelihood of risk. Available acute dose-based toxicity data for granules indicates greater toxicity than TGAI; thus, RQs are greater when based on granule toxicity.

Banded application methods result in higher RQs than in-furrow or knifed-in application methods. Soil incorporation using conventional commercial equipment greatly reduces the number of exposed granules, but does not eliminate potential exposure. The risk assessment assumes that 15% of granules are exposed and available for banded applications and 1% are exposed for in-furrow and knifed-in applications. However, varying numbers of exposed granules may result from each type of use specified on terbufos labels.

Exposure values were estimated for along treated rows where some type of incorporation is concurrent with application. The number of granules that may be found in turn areas at row ends where application equipment is raised from the soil may be considerably higher than along rows. Label directions specify incorporating product that is visible on the soil surface in turn areas; however, it may not be practical to do this immediately after granules are deposited and the level of incorporation may not be equal to that along the rows. Therefore, risk at row ends may be greater than suggested by risk along treated rows.

The likelihood of consuming enough terbufos to cause adverse effects is related in part to the number of granules containing that dose and the number of granules readily available for foraging. The fewer the number of granules and the higher the availability, the greater the risk concern. In general, very few granules are required to reach either the acute listed or non-listed species LOCs (**Appendix L**). The number of exposed granules is relatively high in comparison. For birds, the listed species acute LOC is exceeded consuming <1 to 125 granules, depending on the bird weight and terbufos product (CR, 15G, or 20G).[9] For mammals, the listed species acute LOC is exceeded consuming <1 to 10 granules, depending on the mammal weight and terbufos product. Exceedance of the non-listed species acute LOC requires consuming 5 times as many granules. For a given use, the formulation also impacts the likelihood of consuming enough granules to exceed the acute LOCs; a fewer number of CR granules are required than 20G or 15G granules due primarily to their larger size.[10]

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[9] Range is based on formulation toxicity when available instead of TGAI toxicity.

[10] Difference in formulation toxicity is also a factor. Although there is not a complete formulation toxicity dataset for either birds or mammals, available information suggests that differences in granule size may be the primary factor differentiating the formulations in terms of the number of consumed granules that result in a risk concern.

Results from KABAM indicate a risk concern for piscivorus birds and mammals for all uses of terbufos. The results suggest that mammals are more at risk than birds. This assessment is based on the assumption that terbufos is not metabolized by aquatic organisms in the food chain. The assumption is supported by results from the BCF study in conjunction with KABAM estimates of loss rate constants which indicate that metabolism is not a substantial mechanism of depuration for fish (*see* **Section 6.1**); nonetheless, risk may be overestimated to the extent that terbufos is metabolized in different compartments of the aquatic food chain. Although exposure concentrations in water may be high enough to cause mortality in sensitive individuals and species of fish and invertebrates, the potential for bioaccumulation in the food chain may occur in less sensitive individuals and species. In addition, the assessment was based on EECs that do not consider the labeled setbacks and vegetative buffers. Currently available models cannot account for the impact of these buffers (*see* **Section V** for discussion). The potential impact of the buffers was characterized by calculating how effective they would need to be to reduce EECs below the level of concern. Buffers need to be very effective at reducing runoff to eliminate the risk concern; however, in some cases the buffers may be effective enough. As discussed above, it is hypothesized that buffers may reduce loading between 50% and 90%. RQs would be below the acute and chronic LOCs for the scenario with the lowest bioaccumulation potential (ORsweetcorn_OP scenario) if loading is reduced by 75% compared to the "no buffer" EECs. In contrast, the scenario with the highest bioaccumulation potential (MScorn_STD) would require a 95% reduction in loading compared to the "no buffer" EECs to eliminate the risk concern for birds (acute and chronic) and for mammals on an chronic dietary basis while RQs would remain above the acute and chronic LOC on a dose basis for mammals even with a 95% reduction in loading.

The STIR model indicates a potential risk to birds and mammals from vapor inhalation. This is not unexpected given that terbufos is highly toxic (acute inhalation) and semi-volatile. The screen assumes a maximum vapor concentration in air at saturation for 1 hour; therefore, it represents an upper-bound exposure value and provides a conservative estimate of exposure at the screening level. The screen indicates that the ratio of vapor concentration (at saturation) to inhalation toxicity is 108x above the screening threshold of 0.1 for mammals and 40x above the threshold for birds (based on an estimated inhalation toxicity value). Although avian inhalation toxicity data would be useful for better addressing potential risk, it is likely to show that terbufos is highly toxic (as it is to mammals); therefore, indicating a potential risk through vapor inhalation exposure. The vapor pressure (3.16×10^{-4} mm Hg) and Henry's Law Constant (2.22×10^{-5} atm m^3/mol) suggest that some terbufos will dissipate by diffusion into the atmosphere; however, the amount will likely vary depending on site conditions, application methods, and the rate of photodegradation in the atmosphere. For example, exposure from volatilization may be greater for terbufos that remains on the soil surface after incorporation (i.e., along rows and at the end of rows) than for terbufos that is incorporated into the soil. Likewise, lightly incorporated applications may result in greater exposure than applications requiring deeper incorporation. Vapor phase exposure estimates can be refined using a flux rate measured at a representative use site coupled with an air dispersion model (*e.g.*, AERSCREEN or PERFUM). EFED recommends submission of a field volatility study to refine exposure estimates.

Given the results of the conservative screening, exposure to terbufos through volatilization may or may not be a sole cause of adverse effects to non-target animals; however, the screening does suggest that when aggregated with other routes of exposure (i.e., diet, drinking water, and dermal), terbufos exposure through vapor inhalation may contribute to a total exposure that has potential for effects to non-target animals.

The SIP model indicates a potential risk to birds and mammals from acute and chronic exposure to terbufos contaminated drinking water. This screening is qualitative, is based on drinking water exposure alone, and is based on several conservative assumptions which add considerable uncertainty to this risk conclusion (*see* **Appendix J**). Nonetheless, when aggregated with other routes of exposure (i.e., diet, inhalation, and dermal), terbufos exposure through drinking water may contribute to a total exposure that has potential for effects to non-target animals.

The open literature data for acute toxicity to birds (discussed in **Section IV**) were not used quantitatively in the risk assessment. The data would not change general conclusions about acute risk to birds; however, it does suggest that acute risk may be greater than that indicated by acute toxicity of the TGAI to bobwhite quail (MRID 00106551).

Overall, the weight of available evidence supports an acute and chronic risk concern for birds and mammals from the labeled use of terbufos. The risk concern based on the LD_{50}/ft^2 assessment is supported by field studies. In addition, bird and mammal incidents are reported in the three incident databases (EIIS, Aggregate Incident Data System, and AIMS), although it is noted that some reported in EIIS may be misuse or misapplications of terbufos. Screening level drinking water and vapor phase exposure estimates suggest a potential risk concern as well. Finally, there is a potential risk concern for piscivorus birds and mammals from consuming terbufos contaminated fish. Cumulative exposure to terbufos from multiple pathways may be an important consideration in the risk of terbufos even if each pathway contributes a small amount to total exposure given that terbufos is highly toxic to birds and very highly toxic to mammals.

Non-Target Terrestrial Invertebrates

Terbufos is a systemic granular pesticide, thus it is translocated into plant tissues after soil applications. Exposure of honeybees to systemic pesticides via soil applications is expected to result primarily from translocation to plant tissues (pollen, nectar, exudates, and honeydew); therefore, it is assumed that the primary route of exposure is through diet (USEPA, 2012b). Exposure may occur from visiting plants on the treatment field. Plants off the treated field may also contain residues if run-off occurs. Bees could be exposed through direct contact with exposed granules; however, this exposure pathway is much less likely and the proposed Tier I exposure methods do not include a methodology for addressing this exposure pathway. Dietary risk could not be assessed because acute and chronic oral toxicity (adult or larval) data are not available for terbufos or phorate, the structural analog of terbufos. Although risk cannot be quantified it is reasonable to expect risk to honeybees given that terbufos is an insecticide and that it is systemic. Submission of acute and chronic oral toxicity data (adult and larval) would be useful for refining and characterizing the degree of risk.

Terrestrial Plants

The LOC (1.0) is not exceeded for listed plants located in dry or semi-aquatic locations (RQs $\leq$ 0.13) from any labeled use. There is no risk from spray drift because the products are applied as a granule. Vegetative vigor toxicity data were not available; however, given the mode of action of terbufos it is assumed that the seedling emergence data are likely representative of potential effects on growth of older plants. Although an EC_{25} was not established in the available seedling emergence study, there is no risk concern for non-listed plants given that there is no risk concern for listed plants.

Some open literature data suggest that effects to plants (phytotoxicity other than growth and survival and field yield) may occur at rates lower to or equal to the 2 lb ai/A NOAEC observed in the registrant submitted data. Effects were observed at concentrations from 1-2 lb ai/A; however, NOAECs were not established. Chlorosis (7 day old corn) and decreased tissue Zn concentration (at harvest) were observed in corn while treated plants showed growth (chlorophyll, height, and weight) that was similar to or greater than control plants later in the growing season. Two field studies showed effects on yield; however, there is inherent uncertainty as to the cause of these effects and the effects did not occur consistently from year to year or site to site.

Only two incidents reported for terbufos in the EIIS database involve effects on plants (corn) and both were likely caused by joint application of other herbicides. In one case the herbicide application was a misuse. In both cases flumetsulam, an ALS-herbicide, was one of two herbicides applied along with terbufos. Terbufos and other OP insecticides increase the risk of plant injury in corn plants due to toxic effects of ALS-herbicides. As such, the terbufos labels provide warnings about the timing of application of terbufos and ALS-herbicides. This interaction occurs because terbufos and ALS-herbicides are degraded by the same enzyme system; thus, the presence of terbufos may reduce the rate of degradation of the herbicide and allow it to accumulate in the plant to toxic levels.[11] Six incidents of minor plant damage are reported in the Aggregate Incident Data System. Details of these incidents are not reported; however, it is certainly possible that they could be related to co-exposure with herbicides given the known interaction of certain herbicides with terbufos.

Based on the weight of evidence there is little risk concern for direct effects to terrestrial plants from the labeled uses of terbufos with the exception of terbufos potentially increasing the toxicity of herbicides such as ALS-inhibitors when both terbufos and the herbicide are taken up by a plant in sufficient quantities.

VIII. Risk to Listed Species

In November 2013, the EPA, along with the U.S. Fish & Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS) (collectively, the Services), and the U.S. Department of Agriculture (USDA) released a summary of their joint Interim Approaches for assessing risks to listed species from pesticides. The Interim Approaches were developed jointly by the agencies in response to the National Academy of Sciences' (NAS) recommendations and reflect

[11] http://www.weeds.iastate.edu/mgmt/qtr00-1/opinteractions.htm

a common approach to risk assessment shared by the agencies as a way of addressing scientific differences between the EPA and the Services. The NAS report outlines recommendations on specific scientific and technical issues related to the development of pesticide risk assessments that EPA and the Services must conduct in connection with their obligations under the Endangered Species Act (ESA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

The joint Interim Approaches were released prior to a stakeholder workshop held on November 15, 2013. In addition, the EPA presented the joint Interim Approaches at the December 2013 Pesticide Program Dialogue Committee (PPDC) and State-FIFRA Issues Research and Evaluation Group (SFIREG) meetings, and held a stakeholder workshop in April 2014, allowing additional opportunities for stakeholders to comment on the Interim Approaches. As part of a phased, iterative process for developing the Interim Approaches, the agencies will also consider public comments on the Interim Approaches in connection with the development of upcoming Registration Review decisions. The details of the joint Interim Approaches are contained in the white paper "Interim Approaches for National-Level Pesticide Endangered Species Act Assessments Based on the Recommendations of the National Academy of Sciences April 2013 Report," dated November 1, 2013.

Given that the agencies are continuing to develop and work toward implementation of the Interim Approaches to assess the potential risks of pesticides to listed species and their designated critical habitat, this preliminary risk assessment for terbufos does not contain a complete ESA analysis that includes effects determinations for specific listed species or designated critical habitat. Although EPA has not yet completed effects determinations for specific species or habitats, for this preliminary assessment EPA conducted a screening-level assessment for all taxa of non-target wildlife and plants that assumes for the sake of the assessment that listed species and designated critical habitats may be present in the vicinity of the application of terbufos. This screening level assessment will allow EPA to focus its future evaluations on the types of species where the potential for effects exists once the scientific methods being developed by the agencies have been fully vetted. This screening-level risk assessment for terbufos indicates potential risks of direct effects to listed mammals, birds, terrestrial invertebrates, fish, and aquatic invertebrates on all of its registered use sites. Listed species of aquatic and terrestrial plants may also be affected through indirect effects because of the potential for direct effects on listed and non-listed species upon which such species may rely. Potential direct effects on listed mammals, birds, terrestrial invertebrates, fish, and aquatic invertebrates from the use of terbufos may be associated with modification of Primary Constituent Elements (PCEs) of designated critical habitats, where such designations have been made. Once the agencies have fully developed and implemented the scientific methods necessary to complete risk assessments for endangered and threatened (listed) species and their designated critical habitats, these methods will be applied to subsequent analyses for terbufos as part of completing this registration review.

IV. Endocrine Disruptor Screening Program

As required by FIFRA and the Federal Food, Drug, and Cosmetic Act (FFDCA), EPA reviews numerous studies to assess potential adverse outcomes from exposure to chemicals.

Collectively, these studies include acute, subchronic and chronic toxicity, including assessments of carcinogenicity, neurotoxicity, developmental, reproductive, and general or systemic toxicity. These studies include endpoints which may be susceptible to endocrine influence, including effects on endocrine target organ histopathology, organ weights, estrus cyclicity, sexual maturation, fertility, pregnancy rates, reproductive loss, and sex ratios in offspring. For ecological hazard assessments, EPA evaluates acute tests and chronic studies that assess growth, developmental and reproductive effects in different taxonomic groups. As part of registration review of terbufos, EPA reviewed these data and selected the most sensitive endpoints for relevant risk assessment scenarios from the existing hazard database. However, as required by FFDCA section 408(p), terbufos is subject to the endocrine screening part of the Endocrine Disruptor Screening Program (EDSP).

EPA has developed the EDSP to determine whether certain substances (including pesticide active and other ingredients) may have an effect in humans or wildlife similar to an effect produced by a "naturally occurring estrogen, or other such endocrine effects as the Administrator may designate." The EDSP employs a two-tiered approach to making the statutorily required determinations. Tier 1 consists of a battery of 11 screening assays to identify the potential of a chemical substance to interact with the estrogen, androgen, or thyroid (E, A, or T) hormonal systems. Chemicals that go through Tier 1 screening and are found to have the potential to interact with E, A, or T hormonal systems will proceed to the next stage of the EDSP where EPA will determine which, if any, of the Tier 2 tests are necessary based on the available data. Tier 2 testing is designed to identify any adverse endocrine-related effects caused by the substance, and establish a dose-response relationship between the dose and the E, A, or T effect.

Under FFDCA section 408(p), the Agency must screen all pesticide chemicals. Between October 2009 and February 2010, EPA issued test orders/data call-ins for the first group of 67 chemicals, which contains 58 pesticide active ingredients and 9 inert ingredients. A second list of chemicals identified for EDSP screening was published on June 14, 2013[12] and includes some pesticides scheduled for registration review and chemicals found in water. Neither of these lists should be construed as a list of known or likely endocrine disruptors.

Terbufos and terbufos sulfone (degradation product) are on List 2. List 2 represents the next set of chemicals for which EPA intends to issue test orders/data call-ins in the near future. For further information on the status of the EDSP, the policies and procedures, the lists of chemicals, future lists, the test guidelines and the Tier 1 screening battery, please visit the website.[13]

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[12] http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0477-0074
[13] http://www.epa.gov/endo/

X. References

Note: Open literature toxicity study references from the ECOTOXicology database are listed in Appendix M.

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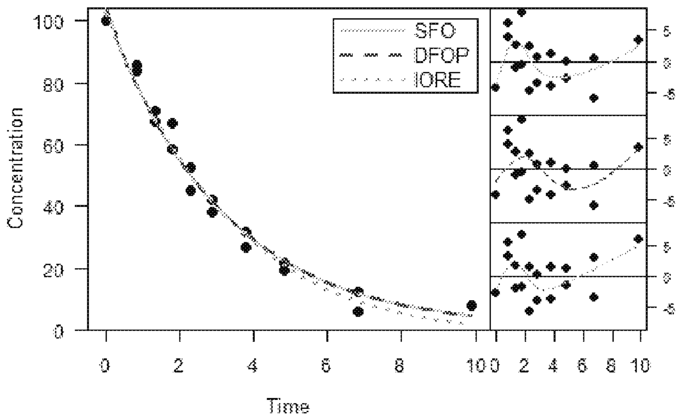
Appendix A: DT_{50s} Submitted Environmental Fate Studies

Hydrolysis (MRID 44862501)

Terbufos pH 7 @ 20°C

DAT (day)	% of Applied
0	100
0	100
0.84	83.6
0.84	85.9
1.33	67.2
1.33	70.9
1.79	58.4
1.79	66.8
2.3	45.2
2.3	52.5
2.88	42.3
2.88	38.1
3.81	32.0
3.81	26.8
4.85	22.1
4.85	19.4
6.8	12.4
6.8	5.98
9.88	7.79



	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	2.17	7.22	4.7	104	k=0.319
DFOP	2.17	7.22	5.2	104	f=0.741, k_1=0.319, k_2=0.319
IORE	2.27	6.58	4.7	103	N=0.819, k=0.662

S_C	274
S_{SFO}	275
Slow $t_{1/2}$	2.17
$t_{R\ IORE}$	1.98

Temperature adjusted DT_{50} @ 25° C is 1.5 days.
The following guidance was used in calculating temperature adjusted DT50s (USEPA, 2009).

Guidance

When aerobic or anaerobic aquatic metabolism rates are derived from studies conducted at other than 25°, they should be adjusted before entering them into EXAMS or PE5. The adjustment should be as follows:

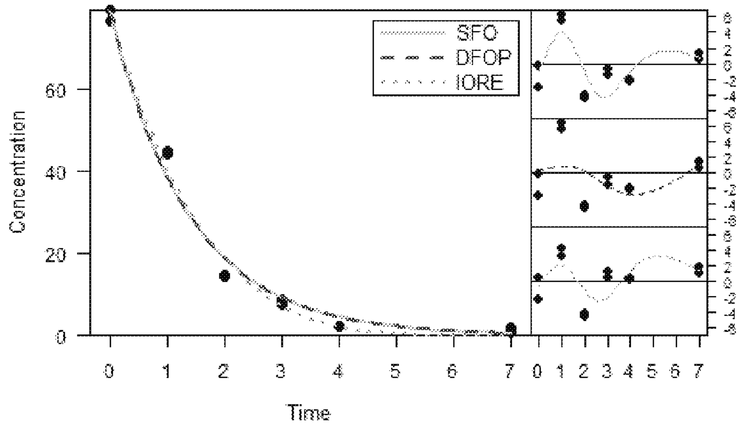
$$\mu_{input} = \left[2^{\left(\frac{25-T_{exp}}{10}\right)} \right] \mu_{measured} \qquad (2)$$

μ_{input} = input value for metabolism rate , [day^{-1}]
$\mu_{measured}$ = laboratory measured aerobic metabolism rate , [day^{-1}]
T_{exp} = temperature of laboratory study [°C].

Aquatic Photolysis (MRID 41181101)

Aquatic Photolysis - Terbufos (Irradiated)

DAT	% of Applied
0	76.5
0	79.2
1	44.2
1	45.1
2	14.8
2	14.4
3	8.60
3	7.70
4	2.50
4	2.30
7	1.00
7	1.80

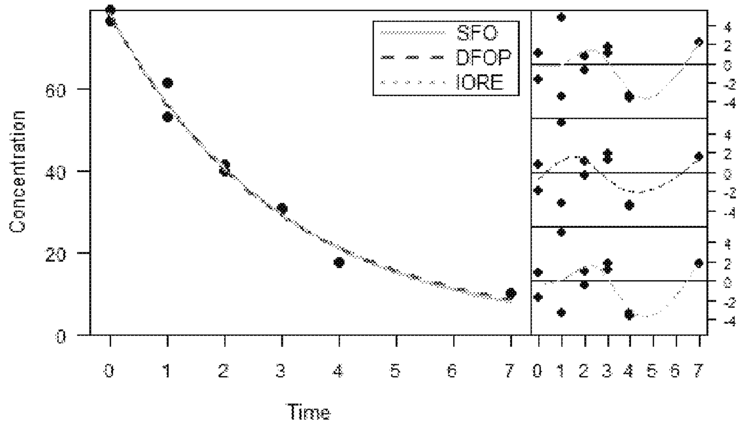


	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	0.966	3.21	10	79.5	k = 0.718
DFOP	0.966	3.21	13	79.5	f = 0.88, k_0 = 0.718, k_1 = 0.718
IORE	1.05	2.93	8.6	78.8	N = 0.765, k = 1.7

S_C	97.7
S_{SFO}	129
Slow $t_{1/2}$	0.966
$t_{R\ IORE}$	0.882

Aquatic Photolysis - Terbufos (Dark Control)

DAT	% of Applied
0	76.5
0	79.2
1	52.9
1	61.2
2	41.4
2	40.0
3	31.0
3	30.4
4	17.9
4	17.6
7	10.1
7	10.1



	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	2.12	7.04	3.6	78.2	k = 0.327
DFOP	2.09	7.31	4.5	78.4	f = 0.856, k_0 = 0.365, k_1 = 0.172
IORE	2.1	7.17	3.9	78.3	N = 1.03, k = 0.289

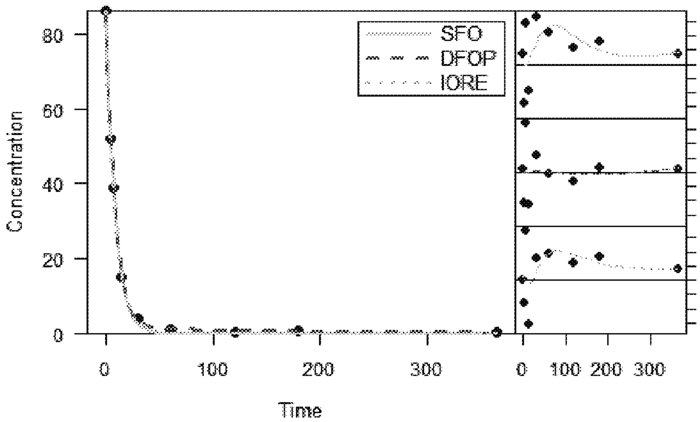
S_C	97.9
S_{SFO}	76.7
Slow $t_{1/2}$	4.02
$t_{R\ IORE}$	2.16

Estimated DT_{50} is 1.77 days @ 25° C.

Aerobic Soil Metabolism (MRID 00156853)

Aerobic Soil Study (Terbufos)

DAT	% of Terbufos
0	86.2
4	52.1
7	38.9
14	15.4
30	4.10
60	1.20
120	0.600
180	0.800
365	0.380



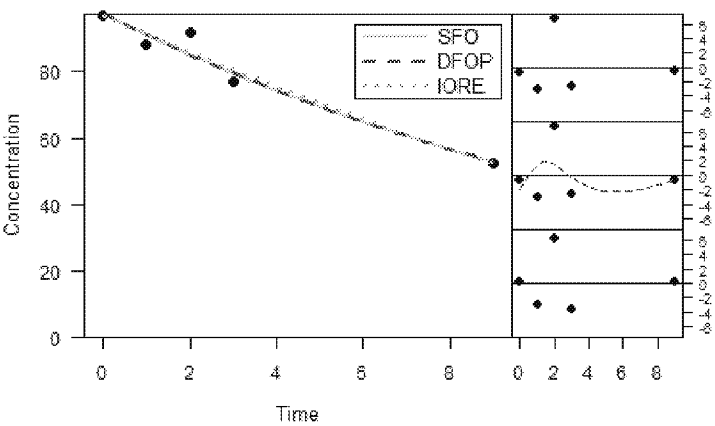
	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	5.85	19.4	3.8	85.9	k = 0.118
DFOP	5.77	20.1	3.3	86.1	f = 0.981, k_2 = 0.123, k_1 = 0.00505
IORE	5.74	20.4	3.7	86.2	N = 1.08, k = 0.086

S_C	12.5
S_{SFO}	10
Slow $t_{1/2}$	137
$t_{R\ IORE}$	6.14

Aerobic Soil Metabolism (MRID 41181101)

Aerobic Soil Study (Terbufos)

DAT	% of Terbufos
0	96.9
1	88.1
2	92.0
3	77.0
9	52.3



	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	10.2	33.8	3.5	97.6	k = 0.0681
DFOP	10.2	33.8	5	97.6	f = 0.405, k_2 = 0.0681, k_1 = 0.0681
IORE	9.91	22.3	3.9	96.7	N = 0.439, k = 0.754

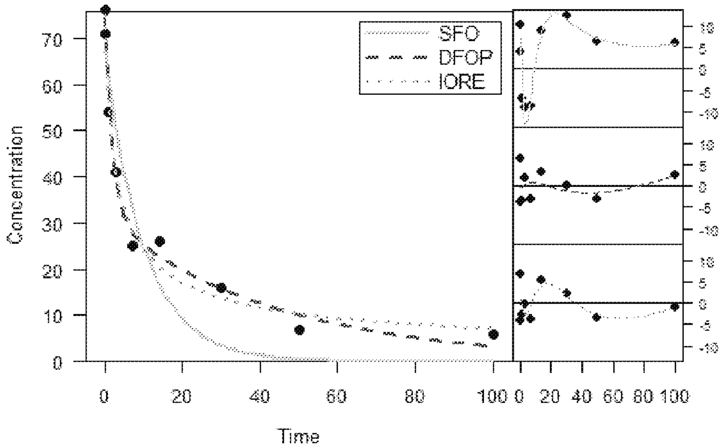
S_C	164
S_{SFO}	63.5
Slow $t_{1/2}$	10.2
$t_{R\ IORE}$	6.71

The 90th percentile DT_{50} is 14.7 days.

Aerobic Aquatic Metabolism (MRID 44672204)

Loam Sediment-Terbufos

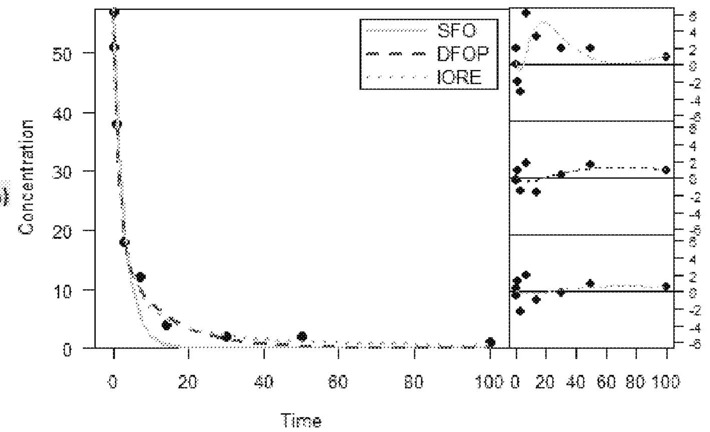
DAT	Terbufos In total System (%)
0	71.0
0.25	76.0
1	54.0
3	41.0
7	25.0
14	26.0
30	16.0
50	7.00
100	6.00



	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
						S_C	195
SFO	7.04	23.4	19	67.1	k = 0.0985	S_{SFO}	645
DFOP	3.33	63	8.6	74.9	f = 0.583, k_2 = 0.491, k_1 = 0.0226	Slow $t_{1/2}$	30.6
IORE	3.8	89.6	9.1	75	N = 2.76, k = 0.000181	$t_{R\ IORE}$	27

Sand Sediment-Terbufos

DAT	Terbufos In total System (%)
0	57.0
0.25	51.0
1	38.0
3	18.0
7	12.0
14	4.00
30	2.00
50	2.00
100	1.00



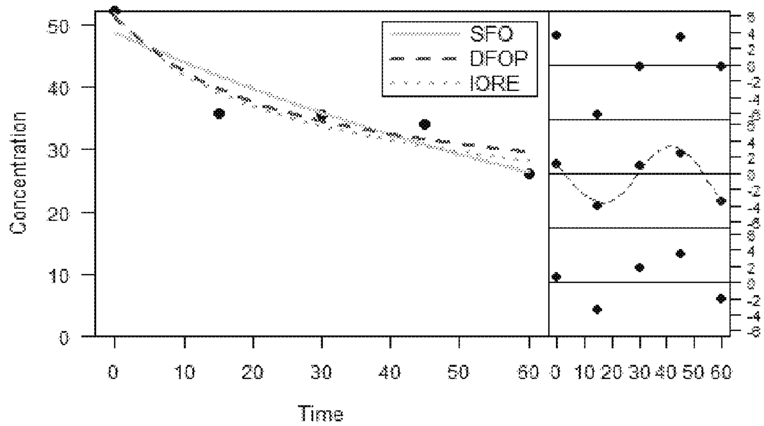
	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
						S_C	19
SFO	2.17	7.22	11	55.1	k = 0.319	S_{SFO}	75.3
DFOP	1.69	13.8	5.2	57.3	f = 0.704, k_2 = 0.633, k_1 = 0.0789	Slow $t_{1/2}$	8.79
IORE	1.72	12.2	5	57.5	N = 1.79, k = 0.022	$t_{R\ IORE}$	3.66

The temperature adjusted 90th percentile DT_{50} @ 25° C is 36.2 days.

Anaerobic Soil Metabolism (MRID 41749801)

Anaerobic Soil Study (Terbufos)

DAT	% of Terbufos
0	52.3
15	35.7
30	35.5
45	34.0
60	26.1



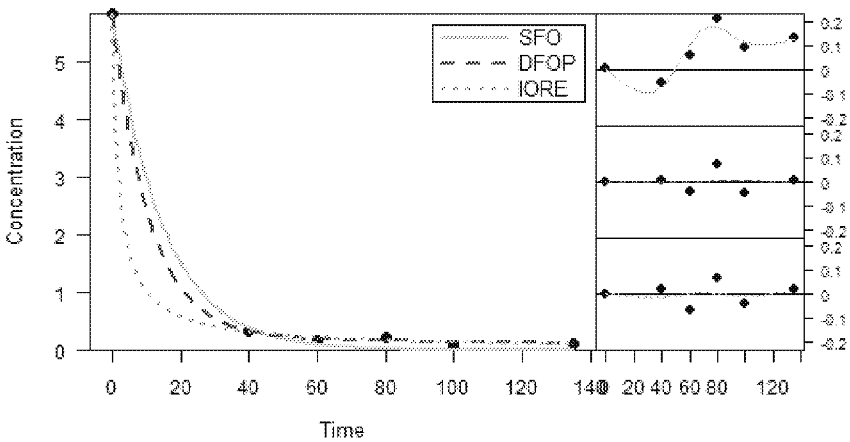
	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	67.5	224	7.6	48.8	k = 0.0103
DFOP	99.1	567	8.4	51.2	f = 0.298, k_0 = 0.0666, k_1 = 0.00343
IORE	81	12660	6.3	51.8	N = 4.06, k = 1.68e-07

S_C	86.6
S_{SFO}	60.7
Slow $t_{1/2}$	202
$t_{R\ IORE}$	3.81e+03

Terrestrial Field Dissipation (MRID 0087708)

Field Dissipation-Terbufos (0-3 inches)

DAT	PPM
0	5.86
40	0.340
60	0.160
80	0.240
100	0.100
135	0.130



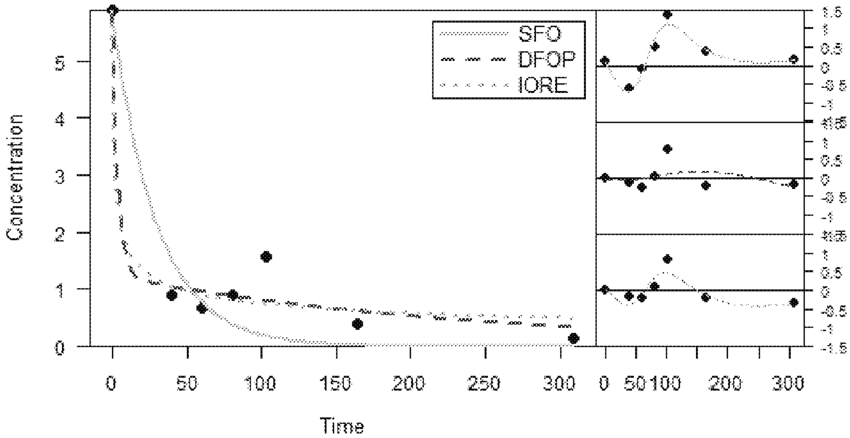
	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	10.3	34.2	7.9	5.86	k = 0.0674
DFOP	7.89	29	3.5	5.86	f = 0.959, k_0 = 0.0929, k_1 = 0.00493
IORE	2.01	20	3.3	5.86	N = 2.08, k = 0.0756

S_C	0.0223
S_{SFO}	0.0772
Slow $t_{1/2}$	141
$t_{R\ IORE}$	6.01

Terrestrial Field Dissipation (MRID 0087706)

Field Dissipation-Terbufos (0-3 inches)

DAT	PPM
0	5.90
40	0.890
60	0.680
80	0.900
103	1.56
164	0.400
309	0.150

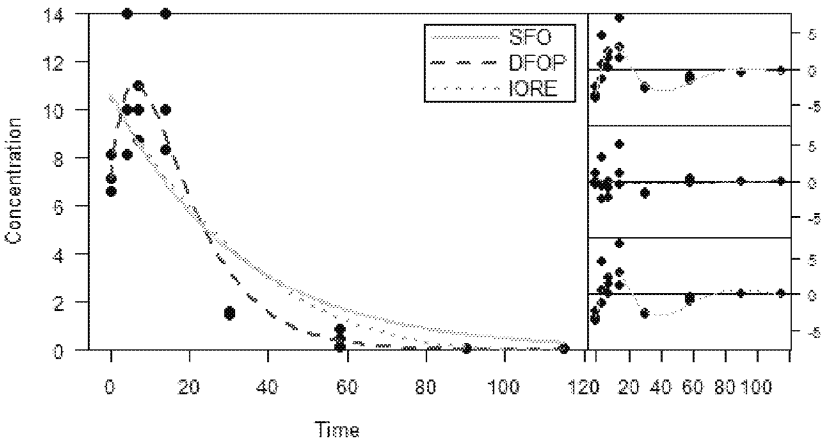


	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
SFO	20.8	69.1	33	5.8	k = 0.0333	S_C	1.57
DFOP	3.71	175	21	5.9	f = 0.791, k_0 = 0.267, k_1 = 0.00421	S_{SFO}	2.72
IORE	2.18	189	21	5.9	N = 3.67, k = 0.00811	Slow $t_{1/2}$	165
						$t_{R\ IORE}$	56.8

Terrestrial Field Dissipation (MRID 41883101 and 41883102)

Field Dissipaton-Terbufos (0-6 inches)

DAT	PPM
0	7.10
0	8.10
0	6.60
4	10.0
4	8.10
4	14.0
7	8.70
7	11.0
7	10.0
14	10.0
14	8.30
14	14.0
30	1.50
30	1.60
30	1.60
58	0.450
58	0.860
58	0.140
90	0.0500
90	0.0600
90	0.0500
115	0.0500
115	0.0500
115	0.0500

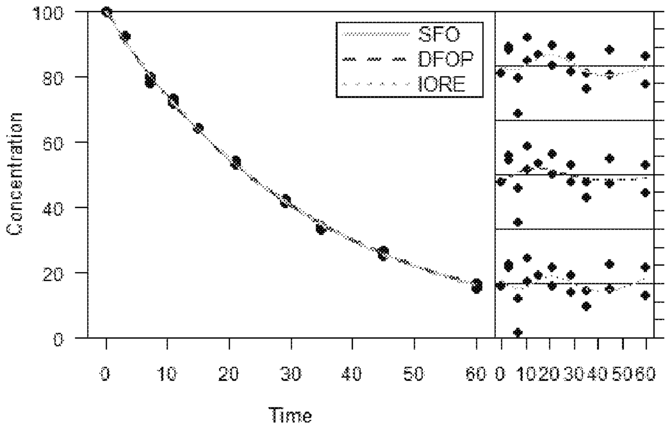


	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
SFO	22.2	73.9	34	10.7	k = 0.0312	S_C	160
DFOP	28.8	NA	18	7.13	f = 6.28, k_0 = 0.0818, k_1 = 0.139	S_{SFO}	156
IORE	24.2	62.5	35	10.5	N = 0.659, k = 0.0568	Slow $t_{1/2}$	8.48
						$t_{R\ IORE}$	18.8

Hydrolysis (MRID 44862501)

Terbufos Sulfoxide pH 7 @ 40°C

DAT (day)	% of Applied
0	100.
0	100.
3.05	92.4
3.05	92.6
7.06	78.5
7.06	80.4
11	73.6
11	72.3
15	64.4
15	64.4
21	54.4
21	53.3
29	42.3
29	41.4
35	34.5
35	33.6
45	26.7
45	25.3
60	16.9
60	15.4



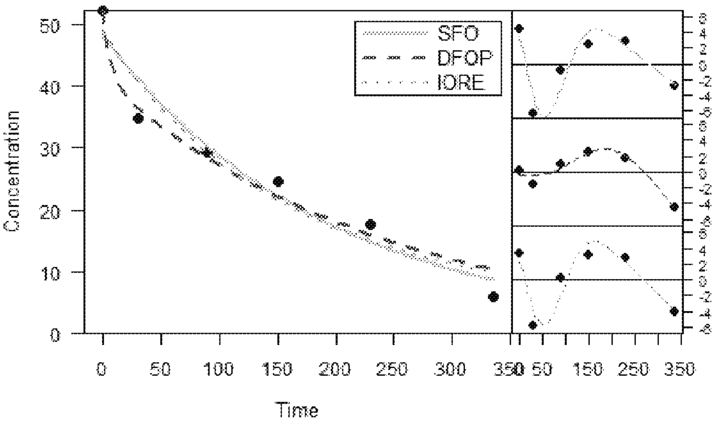
	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
SFO	23	76.3	1.1	100	k = 0.0302	S_C	20.5
DFOP	23	76.3	1.2	100	f = 0.625, k_0 = 0.0302, k_1 = 0.0302	S_{SFO}	18.6
IORE	23.2	74.8	1.1	100	N = 0.966, k = 0.0346	Slow $t_{1/2}$	23
						$t_{R\ IORE}$	22.5

Temperature adjusted DT_{50} @ 25° C is 65.1 days.

Aerobic Soil Metabolism (MRID 00156853)

Aerobic Soil Study (Terbufos Sulfoxide)

DAT	% of Terbufos
0	52.3
30	34.9
90	29.4
150	24.7
230	17.7
335	5.90

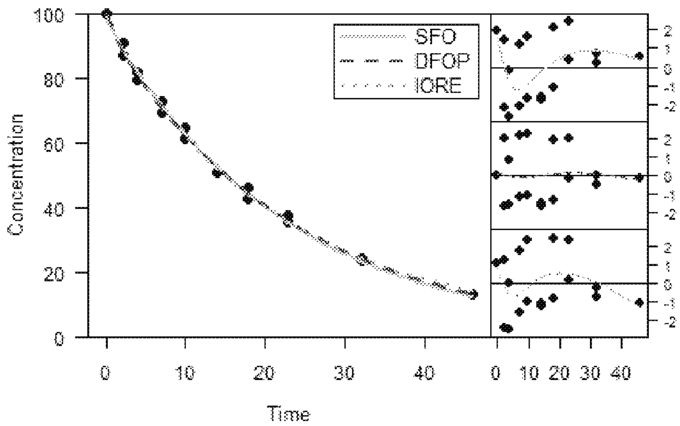


	DT_{50}	DT_{90}	χ^2	C_0	Parameters		
SFO	136	450	11	47.9	k = 0.00511	S_C	158
DFOP	110	502	8.5	52.2	f = 0.213, k_0 = 0.158, k_1 = 0.00411	S_{SFO}	80.4
IORE	124	548	12	49	N = 1.33, k = 0.00175	Slow $t_{1/2}$	168
						$t_{R\ IORE}$	165

Hydrolysis (MRID 44862501)

Terbufos Sulfone pH7@ 40°C

DAT (day)	% of Applied
0	100.
0	100.
2.13	90.6
2.13	87.0
4.03	81.7
4.03	79.3
7.01	72.9
7.01	69.6
9.97	64.5
9.97	61.2
14	50.8
14	51.0
17.9	46.2
17.9	43.0
22.9	37.7
22.9	35.6
32.1	24.1
32.1	23.6
45.9	13.2



	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	15.5	51.6	1.5	98.1	k=0.0446
DFOP	15.1	52.7	0.96	100	f=0.0465, k_0=0.497, k_1=0.0428
IORE	15.1	56	1.3	98.9	N=1.13, k=0.0263

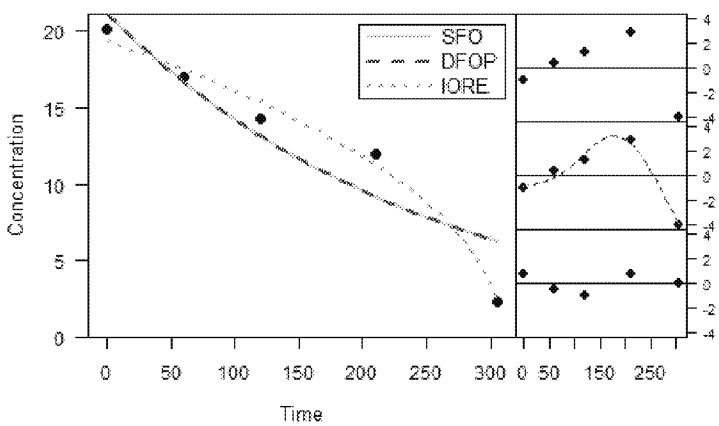
S_C	49.7
S_{SFO}	50.8
Slow $t_{1/2}$	16.2
$t_{R\ IORE}$	16.9

Temperature adjusted DT_{50} @ 25° C is 43.8 days.

Aerobic Soil Metabolism (MRID 00156853)

Aerobic Soil Study (Terbufos Sulfone)

DAT	% of Terbufos
0	20.1
60	17.0
120	14.3
210	12.0
305	2.30

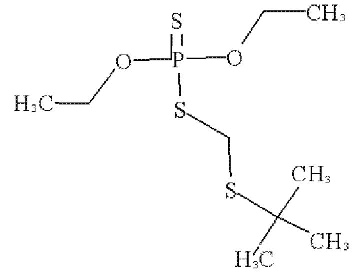
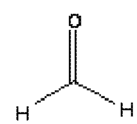
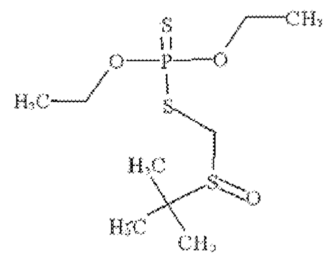


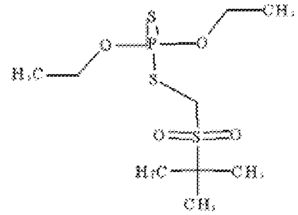
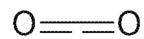
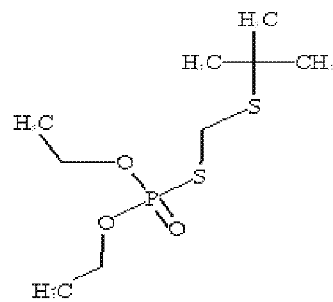
	DT_{50}	DT_{90}	χ^2	C_0	Parameters
SFO	174	579	14	21.1	k=0.00398
DFOP	174	579	20	21.1	f=0.637, k_0=0.00398, k_1=0.00398
IORE	237	306	4.8	19.3	N=-1.11, k=0.793

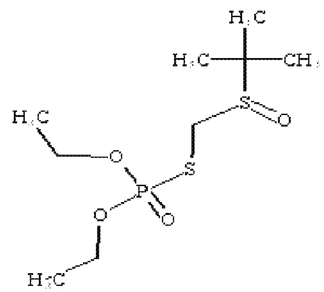
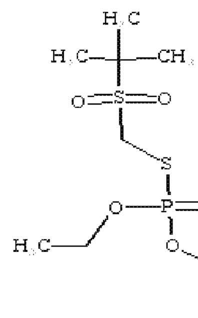
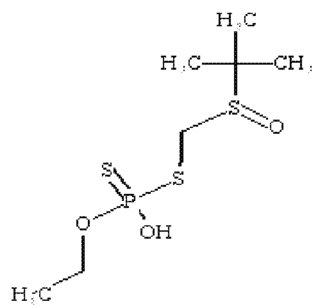
S_C	6.38
S_{SFO}	26.5
Slow $t_{1/2}$	174
$t_{R\ IORE}$	92.2

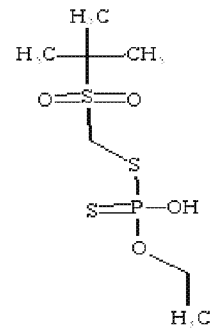
Appendix B: Degradate Formation in Fate Studies

Table B-1. Terbufos and Its Environmental Transformation Products

Common Name (Synonym)	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR[1] (day)	Final %AR[1] (day)
Parent						
Terbufos (AC 92100)	S-[[(1,1-dimethylethyl)thio]methyl]O,O-diethylphosphorodithioate CAS No.: 13071-79-9 Formula: $C_9H_{21}O_4P_1S_3$ MW: 288.4 g/mol SMILES: CCOP(=S)(OCC)SCSC(C)(C)C		Hydrolysis	00087694	NA	117.7-22.63 (28d)
				44862501		7.22-16.6 (1.6-30 d)
			Aqueous photolysis	00161567		3.2 (6 d)
				44927918		11.3 (7 d)
			Aerobic soil	00156853		NR
			Anaerobic soil	41749801		82.7 (60 d)
			Aerobic aquatic metabolism	44862502[2]		0.5-12 (161-189 d)
			Terrestrial field dissipation	00087708		0.02 (100 d)
Major (>10%) Transformation Products						
Formaldehyde (Degradate A)[3]	Formaldehyde Formula: CH_2O CAS No.: 000050-00-0 MW: 30.03 g/mol SMILES: O=C		Hydrolysis	00087694	**69.9** (28 d)	**69.9** (28 d)
				44862501	**96.1** (1.6 d)	**96.1** (1.6 d)
			Aqueous photolysis	00161567	**71.9** (6 d)	**71.9** (6 d)
				44862502[2]	**33.8** (2 d)	NR (30 d)
				44862502[3]	**16.9** (30 d)	**16.9** (30 d)
				44862502[3]	**35.2** (30 d)	**35.2** (30 d)
				41181101	Detected, not quantified	
Terbufos sulfoxide (CL 94301)	S-[[(1,1-dimethylethyl)sulfinyl]methyl] O,O-diethylphosphorodithioate Formula: $C_9H_{21}O_3P_1S_3$ MW: 304.42 g/mol SMILES: [CCOP(=S)(OCC)SCS(=O)C (C)(C)C		Aerobic soil	00156853	**52.3** (30 d)	5.9 (365 d)
			Anaerobic soil	41749801	6.2 (15 d)	3.8 (60 d)
			Aerobic aquatic	44862502 [2]	9.98 (3 d)	NR (30 d)
			Terrestrial field dissipation	00087708	0.580	0.02 (100 d)

Common Name (Synonym)	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR[1] (day)	Final %AR[1] (day)
Terbufos sulfone (CL94320)	S-[[(1,1-dimethylethyl)sulfonyl]methyl] O,O-diethylphosphorodithioate Formula: $C_9H_{21}O_4P_1S_3$ MW: 320.42g/mol SMILES: CCOP(=O)(OCC)SCS(=O)(=O)C(C)(C)C		Aerobic soil	00156853	**20.1** (60 d)	2.3 (365 d)
			Anaerobic soil	41749801	4.0 (15 d)	3.7 (60 d)
			Aerobic aquatic	44862502[2]	1.82 (30 d)	1.82 (30 d)
			Terrestrial field dissipation	00087708	0.12 (80 d)	0.02 (100 d)
Carbon dioxide	Carbon dioxide Formula: CO_2 MW: 44.1 g/mol SMILES: O=C=O		Aerobic soil	00156853	**46** (365 d)	**46** (365 d)
			Anaerobic soil	41749801	3.1 (30 d)	2.0 (60 d)
			Aerobic aquatic	44862502[2]	**61.8** (30 d)	**61.8** (30 d)
Minor (<10%) Transformation Products						
Terbufoxon (CL94221)	S-[[(1,1-dimethylethyl)thio]methyl]O,O-diethylphosphorothioate Formula: $C_9H_{21}O_3P_1S_2$ MW: 272.36 g/mol SMILES: C(C)(C)(C)SCSP(=O)(OCC)OCC		Anaerobic soil	41749801	1.7 (15 d)	1.3 (60 d)

Common Name (Synonym)	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR[1] (day)	Final %AR[1] (day)
Terbufoxon sulfoxide (CL94365)	S-[[(1,1-dimethylethyl)sulfinyl]methyl] O,O-diethylphosphorothioate Formula: $C_9H_{21}O_4P_1S_2$ MW: 288.36 g/mol SMILES: C(C)(C)(C)S(=O)CSP(=O)(OC C)OCC		Aerobic soil	00156853	0.5 (7 d)	ND (365 d)
			Anaerobic soil	41749801	2.6 (60 d)	2.6 (60 d)
Terbufoxon sulfone (CL94302)	S-[[(1,1-dimethylethyl)sulfonyl]methyl] O,O-diethylphosphorothioate Formula: $C_9H_{21}O_4P_1S_2$ MW: 304.36 g/mol SMILES: C(C)(C)(C)S(=O)(=O)CSP(=O)(OCC)OCC		Anaerobic soil	41749801	3.1 (30 d)	2.0 (60 d)
Des-ethyl terbufos sulfoxide (CL 1008534)	S-[[(1,1-dimethylethyl)sulfonyl]methyl] O,O-diethyl ester Formula: $C_7H_{17}O_3P_1S_3$ MW: 276.37 g/mol SMILES: C(C)(C)(C)S(=O)CSP(O)(=S)O CC		Aerobic aquatic	44862502[2]	2.14 (7 d)	ND (30 d)

Common Name (Synonym)	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR[1] (day)	Final %AR[1] (day)
Des-ethyl terbufos sulfone (CL 1008533)	S-[[(1,1-dimethylethyl)sulfonyl]methyl] O-ethyl ester Formula: $C_7H_{17}O_4P_1S_3$ MW: 276.37 g/mol SMILES: C(C)(C)(C)S(=O)(=O)CSP(O)(=S)OCC		Aerobic aquatic	44862502[2]	2.85 (14 d)	ND (30d)
Unextracted Residues						
Unextracted residues	NA	NA	Anaerobic soil	41749801	9.2 (60 d)	9.2 (60 d)

NA = not applicable; NR = not reported; ND = not detected

BOLD = formation > 10% of that applied

[1] Applied radioactivity

[2] No sediment was used in the study.

[3] Designated as "Degradate A" in hydrolysis study.

Appendix C: Submitted Toxicity Data

Table C-1. Summary of Toxicity of Terbufos to Aquatic Animals

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Bluegill sunfish (*Lepomis macrochirus*)	96 hr (static)	86	LC_{50} = 0.77 (0.72-0.83)[1] μg ai/L (nom)[2] Probit slope = 14.35 (8.33-20.38)[1] Sublethal effects: pectoral fin erection, and partial loss of equilibrium	00087718	Very Highly Toxic	Supplemental (test concentrations were not measured)	Unknown if sublethal effects observed in surviving fish. NOAEC = 0.37 μg ai/L LOAEC = 0.65 μg ai/L (mortality and sublethal effects)
		86.3	LC_{50} = 3.8 (2.8-4.9)[1] μg ai/L (nom) (binomial test)	00037483	Very Highly Toxic	Supplemental (test concentrations were not measured)	No sublethal effects reported for surviving fish. NOAEC = 2.8 μg ai/L LOAEC = 3.7 μg ai/L (mortality)
	96 hr (flow-through)	88.6	LC_{50} = 0.87 (0.77-1.0)[1] μg ai/L (nom)[2] Probit slope = 5.48 (3.69-7.28)[1]	00085176	Very Highly Toxic	Supplemental (test concentrations were not measured)	No sublethal effects reported for surviving fish. NOAEC = 0.32 μg ai/L LOAEC = 0.42 μg ai/L (mortality)
	96 hr (static)	88	LC_{50} = 1.1 (0.8-1.6)[1] μg ai/L (nom)	40098001	Very Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported. 9 independent tests; 96 hr LC_{50} ranged from 1.1 to 2.4 μg ai/L (nom)
		15	LC_{50} = 1.7 (1.2-2.4)[1] μg ai/L (nom)				Sublethal effects and NOAEC not reported.
			LC_{50} = 12.3 (9.8-15.2)[1] μg formulation/L (nom) Probit slope = 5.4 (3.1-7.6)[1] LC_{50} = 1.8 (1.5-2.3)[1] μg ai/L (nom)	FE0TER04	Very Highly Toxic	Supplemental (test concentrations were not measured)	Counter 15G No sublethal effects reported. NOAEC = 3.7 μg formulation/L LOAEC = 5.6 μg formulation/L (mortality)
	NA	NA	NOAEC = 0.10 μg ai/L[3]	NA	NA	NA	Acute to Chronic ratio based on rainbow trout data.

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Brown trout (*Salmo trutta*)	96 hr (static)	86	LC_{50} = 20 (12-34)[1] µg ai/L (nom)[2] Probit slope = 1.47 (0.95-1.98)[1] Sublethal effects: partial loss of equilibrium	00087718	Very Highly Toxic	Supplemental (test concentrations were not measured)	Unknown if sublethal effects observed in surviving fish. NOAEC = 3.2 µg ai/L LOAEC = 10 µg ai/L (mortality and sublethal effects)
Channel Catfish (*Ictalurus punctatus*)	144 hr (flow-through)	88.6	LC_{50} = 9.6 (8.5-11.07)[1] µg ai/L (nom) (moving average)[2]	00085176	Very Highly Toxic	Supplemental (test concentrations were not measured)	No sublethal effects reported for surviving fish. NOAEC = 4 µg ai/L LOAEC = 5 µg ai/L (mortality) Test conducted for 144 hrs. Toxicity at 144 hrs was slightly greater than at 96 hrs.
	96 hr (static)	15	LC_{50} = 1800 (1230-2640)[1] µg ai/L (nom)	40098001	Moderately Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported.
Fathead minnow (*Pimephales promelas*)	96 hr (static)	88	LC_{50} = 390 (237-643)[1] µg ai/L (nom)	40098001	Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported.
		15	LC_{50} = 150 (101-223)[1] µg ai/L (nom)				
Rainbow trout (*Oncorhynchus mykiss or Salmo gairdneri**)	96 hr (static)	86.3	LC_{50} = 9.4 (7.7-11.4)[1] µg ai/L (nom) Probit slope = 6.2 (3.4-8.9)[1] µg ai/L	00037483	Very Highly Toxic	Supplemental (test concentrations were not measured)	No sublethal effects reported for surviving fish. NOAEC = 4.9 µg ai/L LOAEC = 7.5 µg ai/L (mortality) **Salmo gairdneri*
		88	LC_{50} = 7.6 (6-9.7)[1] µg ai/L (nom)	40098001	Very Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported. 9 independent tests; 96 hr LC_{50} ranged from 7.6 to 15.3 µg ai/L (nom) **Salmo gairdneri*
		15	LC_{50} = 8.8 (6.4-12.1)[1] µg ai/L (nom)				Sublethal effects and NOAEC not reported. **Salmo gairdneri*

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Rainbow trout (*Oncorhynchus mykiss or Salmo gairdneri**)	96 hr (static)	15	LC_{50} = 59.7 (48.1-74.3)[1] µg formulation/L (nom) Probit slope = 5.5 (3.2-7.9)[1] µg formulation/L LC_{50} = 8.9 (7.2-11.1)[1] µg ai/L (nom)	FE0TER05	Very Highly Toxic	Supplemental (test concentrations were not measured)	Counter 15G No sublethal effects reported for surviving fish. NOAEC = 21 µg formulation/L LOAEC = 32 µg formulation/L (mortality) **Salmo gairdneri*
	ELS	98.5	NOAEC ≥ 1.4 µg ai/L (mm)	40009301	NA	Supplemental	**Salmo gairdneri*
		98.99	NOAEC = 0.64 µg ai/L (mm) LOAEC = 1.4 µg ai/L (mm) based on reduced wet weight and length	41475802	NA	("Core") Acceptable	Effects at highest two test concentrations (2.7 and 5.3 µg ai/L): reduced survival, resting on lateral surfaces, hypersensitivity, loss of equilibrium, irregular respiration, dark discoloration, surfacing, and quiescence. Several fish at various concentrations developed spinal curvature and malformed otic capsules. **Oncorhynchus mykiss*

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Waterflea *(Daphnia magna)*	48 hr (static)	88.6	EC_{50} = 0.17 (0.15-0.19)[1] µg ai/L (mm) Sublethal effects: erratic swimming, lying on bottom.	00101495	Very Highly Toxic	Supplemental (test material was unstable)	Majority of the daphnids displaying sublethal effects were deceased at 48 hr. NOAEC = 0.107 µg ai/L LOAEC = 0.185 µg ai/L (mortality and sublethal effects)
		88	EC_{50} = 0.4 (0.3-0.5)[1] µg ai/L (nom)	40098001	Very Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported.
		15	EC_{50} = 6.2 (5.1-7.7)[1] µg formulation/L (nom) Probit slope = 6.6 (3.5-9.6)[1] EC_{50} = 0.9 (0.8-1.2)[1] µg ai/L (nom)	FE0TER06	Very Highly Toxic	Supplemental (test concentrations were not measured)	Counter 15G Sublethal effects not reported. NOAEC = 2.1 µg formulation/L LOAEC = 3.2 µg formulation/L (mortality)
	21 day Life-Cycle (flow-through)	98.4	NOAEC = 0.030 µg ai/L (mm) LOAEC = 0.076 µg ai/L (mm) based on growth and reproduction (reduced body length and number of offspring)	00162525	NA	("Core") Acceptable	Some daphnids were observed lying on the bottom/ quiescent on day 19; those organism appear to have been deceased by day 21. Two additional daphnids showed the same effects on day 21.
Gammarus pseudolimnaeus	96 hr (static)	88	LC_{50} = 0.20 (0.1-0.3)[1] µg ai/L (nom)	40098001	Very Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported.
Chironomus plumosus	48 hr (static)	88	EC_{50} = 1.4 (1.0-2.0)[1] µg ai/L (nom)	40098001	Very Highly Toxic	Myer and Ellersieck, 1986	Sublethal effects and NOAEC not reported.
Crayfish (*Procambarus clarkii*)	96 hr (flow through)	88.6	LC_{50} = 8.0 (6.9-10.2)[1] µg ai/L (nom)[2] Probit slope = 3.36 (2.34-4.38)[1]	00085176	Very Highly Toxic	Supplemental (test concentrations were not measured)	No sublethal effects reported for surviving crayfish. NOAEC = 2.4 µg ai/L LOAEC = 3.2 µg ai/L (mortality)

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Sheepshead minnow (*Cyprinodon variegatus*)	96 hr (static)	98.4	LC_{50} = 1.6 (0.77-3.2)[1] µg ai/L (mm) (binomial test) Sublethal effects: surfacing, loss of equilibrium, and fish at the bottom of the test chamber.	00162524	Very Highly Toxic	Supplemental (due to low dissolved oxygen concentrations at 96 hr)	NOAEC < 0.37 µg ai/L LOAEC ≤ 0.37 µg ai/L (sublethal effects) At the lowest test concentration, sublethal effects (only observed at 96 hr) may have been due to stress from low dissolved oxygen, terbufos, or both.
	96 hr (flow-through)	98	LC_{50} = 3.2 (2.7-3.7)[1] µg ai/L (mm) Probit slope = 7.1 (3.8-10.4)[1] µg ai/L Sublethal effects: loss of equilibrium, floating at the surface, forward pointing pectoral fins, erratic swimming, labored respiration, quiescence, fish at the bottom of the test chamber, and surfacing.	41373602	Very Highly Toxic	("Core") Acceptable	NOAEC < 1.4 µg ai/L LOAEC ≤ 1.4 µg ai/L (sublethal effects)
	NA	NA	NOAEC = 0.14 µg ai/L[4]	NA	NA	NA	Acute to Chronic ratio based on rainbow trout data.
Mysid shrimp (*Americamysis bahia*)	96 hr (static)	98.4	LC_{50} = 0.22 (0.14-0.35)[1] µg ai/L (mm) Probit slope = 2.51 (1.44-3.58)[1] Sublethal effects: quiescence, lying on bottom, and surfacing	00162523	Very Highly Toxic	Supplemental (MRID 00162523 and 41297903 primarily due to excessive control mortality in either the negative or solvent control but not both)	NOAEC = 0.07 µg ai/L LOAEC = 0.13 µg ai/L (mortality and sublethal effects; taking control mortality into consideration) Sublethal effects observed at 0.13 to 0.59 µg ai/L.

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEC /LOAEC for acute studies
Mysid shrimp (*Americamysis bahia*)	96 hr (flow-through)	98	LC_{50} = 0.40 (0.34-0.48)[1] µg ai/L (mm) (moving average) Sublethal effects: quiescence, lying on bottom, surfacing, and loss of equilibrium	41297903	Very Highly Toxic	Supplemental (see MRID 00162523 above)	NOAEC = 0.15 µg ai/L LOAEC = 0.24 µg ai/L (mortality; taking control mortality into consideration) Sublethal effects observed at 0.35 and 0.71 µg ai/L.
		99.9	LC_{50} = 0.543 (0.474-0.623)[1] µg ai/L (mm) (Untrimmed Spearman-Kärber) Sublethal effects: erratic swimming, gyrating motions, and lethargy	42306701	Very Highly Toxic	Acceptable	NOAEC = 0.225 µg ai/L LOAEC = 0.441 µg ai/L (mortality and sublethal efffects)
	NA	NA	NOAEC = 0.041 µg/L[5]	NA	NA	NA	Acute to Chronic ratio based on daphnia data.
Eastern oyster (*Crassostrea virginica*)	96 hr (flow-through)	89.2	EC_{50} = 201 µg ai/L (176-231)[1] µg ai/L (mm) (moving average)	42381501	Highly Toxic	("Core") Acceptable	NOAEC < 54 µg ai/L (22 to 29% inhibition compared to negative control at lowest three test levels)

mm = mean measured; nom = nominal concentration; NA = not applicable
– See DERs for more complete explanations of study classifications.
[1]Range is 95% confidence interval.
[2] It is uncertain if test concentrations were adjusted for purity of the test material.
[3] Bluegill sunfish sensitivity to terbufos on a chronic basis was estimated using an acute to chronic ratio (ACR) because it is the most acutely sensitive species. The ACR was based on rainbow trout (acute and chronic toxicity) and bluegill sunfish (acute toxicity) data. Numerous acute TGAI toxicity endpoints were available for rainbow trout (10) and bluegill sunfish (12) from reliable studies. An average toxicity value from these studies was used given that the range was 2X (rainbow trout) to 3X (bluegill sunfish), resulting in an ACR of 16.7. One open literature study (Call et. al, 1989) reported a NOAEC (0.34 µg ai/L) for fathead minnow about two times lower than that of the rainbow trout (0.64 µg ai/L, MRID 41475802). The study by Call et al. was classified as qualitative and was not used to calculate an ACR. Nonetheless, results from the Call et al. study support the ACR based on the rainbow trout data; an ACR of 4.5 was reported for fathead minnow based on exposure to terbufos while a mean ACR of 10.4 (range of 4.5 to 27.9) was reported for fathead minnow based on terbufos plus four other organophosphate chemicals. The reported ACR of 4.5 is based on a NOAEC of 1.96 µg ai/L because Call et al. questioned the biological significance of the observed effects on length at lower concentrations; the ACR was 38.2 assuming a NOAEC of 0.34 µg ai/L.
[4] Sheepshead minnow sensitivity to terbufos on a chronic basis was estimated using an ACR because data were not available. The ACR was based on rainbow trout (acute and chronic toxicity) and sheepshead minnow (acute toxicity) data. See footnote 3 regarding use of rainbow trout data to estimate the ACR of 16.7. Two equally reliable acute studies were available for sheepshead minnow; an average acute toxicity value from these studies was used to estimate chronic toxicity to sheepshead minnow given that the range of acute toxicity values was 2X.
[5] Mysid sensitivity to terbufos on a chronic basis was estimated using an ACR because data were not available. The ACR was based on daphnia (acute and chronic toxicity) and mysid (acute toxicity) data. Two equally reliable acute studies with the TGAI were available for daphnia and three were available for mysid. An average acute toxicity value was used for each species when calculating the ACR given the small range of acute values (2.4X for daphnia and 2.5X for mysid).

Table C-2. Summary of Toxicity of Terbufos to Aquatic Plants

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification
Freshwater Algae (*Pseudokirchneriella subcapitata)*	96 hr (static)	89.3	EC_{50} >1.85 mg ai/L (im) NOAEC = 0.399 mg ai/L (im) LOAEC = 1 mg ai/L based on effects to cell density, area under the growth curve, average specific growth rate, and yield.	48689902	NA	Acceptable
Marine Diatom (*Skeletonema grethae*)	96 hr	89.3	EC_{50} > 1.01 mg ai/L (im) NOAEC ≥ 1.01 mg ai/L (im)	48939101	NA	Supplemental (numerous deviations including excessive variation of initial cell density among treatment groups)
Duckweed *(Lemma gibba*)	7 day	89.3	EC_{50} > 4.20 mg ai/L NOAEC = 0.280 mg ai/L LOAEC = 0.630 mg ai/L based on frond number, growth rate of frond number, and yield of frond number	48689901	NA	Acceptable

im = initial measured; NA = not applicable
– See DERs for more complete explanations of study classifications.

Table C-3. Summary of Toxicity of Terbufos to Terrestrial Animals

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Northern Bobwhite Quail (*Colinus virginianus*)	Single oral dose	89.6	LD_{50} =28.6 (22.2-55.9)[1] mg ai/kg bw Probit slope = 4.35 (1.56-7.13) Sublethal effects: clinical signs (lethargy progressing to depression, reduced reaction to external stimuli, loss of coordination, lower limb weakness, prostrate posture, loss of righting reflex, salivation, and lower limb rigidity)	00106551	Highly toxic	("Core") Acceptable	Sublethal effects observed at some point during the exposure period at all doses (≥ 6.81 mg ai/kg bw). Mortality observed at doses ≥ 14.7 mg ai/kg bw.

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Northern Bobwhite Quail (*Colinus virginianus*)	Single oral dose	20	LD_{50} = 250 (147-464)[1] mg formulation/kg bw LD_{50} = 50 (29.4-92.8)[1] mg ai/kg bw Sublethal effects: clinical signs (ataxia, lethargy, inability to walk when aroused, and weakness), reduced body weight, and decreased food consumption (day 1-3, all test concentrations with surviving birds)	40660708	Highly toxic (ai basis)	("Core") Acceptable	Counter 20P NOAEL < 29.4 mg ai/kg bw LOAEL ≤ 29.4 mg ai/kg bw (sublethal effects) Body weight decreased in all treatment groups from day 1-3 or 7. Body weight increased thereafter, recovering to that of control birds by day 21 in the second and third highest treatment groups (higher treatment groups showed 100% mortality).
			LD_{50} = 238 (180-310)[1] mg formulation/kg bw LD_{50} = 47.6 (35.9-62)[1] mg ai/kg bw Probit slope = 3.52 (1.99-5.04) Sublethal effects: clinical signs at unspecified treatment levels (lethargy, ataxia, diarrhea, anorexia, noticeable weight loss, inability to stand, and weak appearance) and reduced body weight and feed consumption in all treatment groups	41508802	Highly toxic (ai basis)	Acceptable	Counter CR NOAEL < 20 mg ai/kg bw LOAEL ≤ 20 mg ai/kg bw (mortality, body weight, and feed consumption)

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Northern Bobwhite Quail (*Colinus virginianus*)	Single oral dose	15	LD_{50} = 295 (215-464)[1] mg formulation/kg bw LD_{50} = 44.3 (32.3-69.6)[1] mg ai/kg bw Sublethal effects: clinical signs (ataxia, lethargy, inability to stand/walk when aroused, dyspnea, muscle tremors, piloerection, and paralysis), reduced body weight, and reduced food consumption (day 1-3 or 7, all test concentrations)	40660707	Highly toxic (ai basis)	("Core") Acceptable	Counter 15G NOAEL < 22.1 mg ai/kg bw LOAEL ≤ 22.1 mg ai/kg bw (sublethal effects) Body weight decreased in all treatment groups from day 1-3. Body weight increased thereafter but by day 21 only the lowest treatment group weight recovered to that of the control birds.
			LD_{50} = 290 (245-344)[1] mg formulation/kg bw LD_{50} = 43.5 (36.7-51.6)[1] mg ai/kg bw Probit slope = 8.61 (4.31-12.9) Sublethal effects: clinical signs in all treatment groups (lethargy, ataxia, diarrhea, anorexia, and inability to walk) and reduced feed consumption in the highest three test concentrations not showing 100% mortality (day 0-3)	41508803	Highly toxic (ai basis)	Acceptable	Counter 15G NOAEL < 15 mg ai/kg bw LOAEL ≤ 15 mg ai/kg bw (clinical signs)

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Northern Bobwhite Quail (*Colinus virginianus*)	8 days (5 days treatment and 3 days observation)	86	LC_{50} = 143 (103-214)[1] ppm ai (moving average) (nom)[2] Sublethal effects: decreased locomotor activity, feather erection, loss of righting reflex, and reduced food consumption	00087717	Highly toxic	Supplemental (test concentrations not measured or demonstrated to be stable)	NOAEC < 25 ppm ai LOAEC ≤ 25 ppm ai (mortality and sublethal effects)
		87.8	LC_{50} = 157 (125-201)[1] ppm ai (nom) Probit slope = 7.2 (3.2-11.2) Sublethal effects: depression (lethargy), reduced reaction to sound and movement, wing droop, loss of coordination, prostrate posture, lower limb rigidity, ruffled appearance, lower limb weakness, reduced body weight gain, and reduced food consumption	00160387	Highly toxic	Supplemental (test concentrations not measured or demonstrated to be stable)	NOAEC = 56.2 ppm ai LOAEC = 100 ppm ai (mortality and clinical signs) Some sublethal effects disappeared by the end of the experiment.
	One-generation Reproduction Study	89	NOAEC < 2 ppm ai (nom)[2]	00085177	NA	Supplemental (test concentrations not measured or demonstrated to be stable and lack of pen-by-pen data)	Possible effects on viable embryos of eggs set at 2 ppm ai. Results cannot be confirmed due to a lack of pen by pen data for statistical analysis.
		89.6	NOAEC ≥ 30 ppm ai (nom)	00161573		("Core") Acceptable	No effects observed at highest test concentration.

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Mallard Duck (*Anas platyrhynchos*)	Single oral dose	20	LD_{50} = 161 (68-316)[1] mg formulation/kg bw LD_{50} = 32.2 (13.6-63.2)[1] mg ai/kg bw Sublethal effects: lethargy, ataxia, and reduced food consumption (day 0-3, all test concentrations)	40660706	Highly toxic (ai basis)	("Core") Acceptable	Counter 20P NOAEL < 13.6 mg ai/kg bw LOAEL ≤ 13.6 mg ai/kg bw (reduced food consumption)
		15	LD_{50} = 88 (0-215)[1] mg formulation/kg bw LD_{50} = 13.2 (0-32.3)[1] mg ai/kg bw Sublethal effects: dyspnea, lethargy, immobility, emesis, and reduced food consumption (day 0-3, all test concentrations)	40660705	Highly toxic (ai basis)	("Core") Acceptable	Counter 15G NOAEL < 6.96 mg ai/kg bw LOAEL ≤ 6.96 mg ai/kg bw (mortality and sublethal effects)
Mallard Duck (*Anas platyrhynchos*)	8 days (5 days treatment and 3 days observation)	86	LC_{50} = 153 (117-198)[1] ppm ai (nom)[2] Probit slope = 5.45 (2.33-8.57) Sublethal effects: decreased locomotor activity, feather erection, loss of righting reflex, and reduced food consumption (all test concentrations)	00087717	Highly toxic	Supplemental (test concentrations not measured or demonstrated to be stable)	NOAEC < 100 ppm ai LOAEC ≤ 100 ppm ai (mortality and sublethal effects) Increasing food avoidance with increasing dose
		86	LC_{50} = 697 (584-1616)[1] ppm ai (moving average) (nom)[2] Sublethal effects: reduced body weight and food consumption (all test concentrations)	00035120	Moderately toxic	Supplemental	NOAEC < 100 ppm ai LOAEC ≤ 100 ppm ai (sublethal effects) Body weight and food consumption showed recovery after exposure period Study author calculated LC_{50} = 520 ppm ai

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Mallard Duck (*Anas platyrhynchos*)	One-generation Reproduction Study	89	NOAEC < 2 ppm ai (nom)[2]	00097892	NA	Supplemental (test concentrations not measured or demonstrated to be stable and lack of pen-by-pen data)	Possible effects on viable embryos of eggs set at 2 ppm ai and other variables at 20 ai ppm. Results cannot be confirmed due to a lack of pen by pen data for statistical analysis. It is also noted that body weight decreased at 2 and 20 ppm ai and increased in the control throughout the study.
		89.6	NOAEC = 5 ppm ai (nom) LOAEC = 15 ppm ai (nom)*	00161574		("Core") Acceptable	*Possible biologically significant (but not statistically significant) effect on embryo viability.
Domestic Hen (*Gallus gallus domesticus*)	Single oral dose	88.8	NA	46293202	NA	Invalid	
Brown-headed Cowbird (*Molothrus ater*)	Single oral dose	20	LD_{50} = 85 (46-151)[1] mg formulation/kg bw LD_{50} = 16.9 (9.2-30.1)[1] mg ai/kg bw Probit slope = 1.59 (0.81-2.37) Sublethal effects: clinical signs at unspecified treatment levels (lethargy, hypersalivation, ataxia, inability to walk or fly, shaking, lying on the side, tachypnea, and agape mouth) and body weight (increase only)	41508804	Highly toxic (ai basis)	Acceptable	Counter CR NOAEL < 3.5 mg ai/kg bw LOAEL ≤ 3.5 mg ai/kg bw (mortality)

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Brown-headed Cowbird (*Molothrus ater*)	Single oral dose	15	LD_{50} = 148 (100-235)[1] mg formulation/kg bw LD_{50} = 22.2 (15.0-35.3)[1] mg ai/kg bw Probit slope = 2.63 (1.46-3.79) Sublethal effects: clinical signs showed remission by day 4 (lethargy, hypersalivation, ataxia, anorexia, difficulty or inability walking or flying, and agape mouth), and reduced feed consumption occurred intermittently at the top two doses	41508805	Highly toxic (ai basis)	Acceptable	Counter 15G NOAEL = 6.96 mg ai/kg bw LOAEL = 10.2 mg ai/kg bw (mortality and clinical signs)
Honeybee (*Apis mellifera*)	Acute contact	TGAI	LD_{50} = 4.09 µg ai/bee Probit slope = 3.54 µg ai/bee	00066220	Moderately toxic	("Core") Acceptable	

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Rat	Acute Oral	89.7	LD_{50} = 1.25 (0.98-1.52)[1] mg ai/kg bw (female) LD_{50} = 2.87 (2.33-4.30)[1] mg ai/kg bw (male) Sublethal effects: tremors, salvation, exophthalmos, and decreased activity. All survivors appeared normal 9 days after dosing.	44021601	Very Highly Toxic	Acceptable	
		19	LD_{50} = 0.836 mg ai/kg bw (female)* LD_{50} = 3.3 mg ai/kg bw (male) Sublethal effects: tremors, exophthalmos, salivation, chromodacyrorrhea, ventral surface staining, diarrhea, decreased activity, blood around nose, diuresis, and ataxia	47512801	Very Highly Toxic	Acceptable	Counter 20G Sublethal effects were observed in animals that did not survive except for males in the 2.4 mg ai/kg bw (12.5 mg/kg bw) dose level. Recovery of those animals generally occurred by three days after dosing. *Confidence intervals could not be calculated due to 0 and 100% mortality for sequential doses (*e.g.*, 0% mortality at 0.59 mg ai/kg bw and 100% mortality at 1.18 mg ai/kg bw for females).

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification	Comments and NOAEL/ LOAEL or NOAEC/ LOAEC for acute studies
Rat	2-generation reproduction	89.6	*Reproductive Effects* NOAEC(L) = 1 ppm ai (0.07 – 0.09 mg ai/kg bw/day) LOAEC(L) = 2.5 ppm ai (0.18 – 0.24 mg ai/kg bw/day) based on decreased pregnancy rate and male fertility *Maternal/Offspring Effects* NOAEC(L) = 1 ppm ai (0.09 mg ai/kg bw/day) LOAEC(L) = 2.5 ppm ai (0.22 – 0.24 mg ai/kg bw/day) based on decreased body weight gain in adult females during lactation and lower pup weights	43649402	NA	Acceptable	*Cholinesterase inhibition* NOAEC(L) = 0.5 ppm ai (0.04 mg ai/kg bw/day) LOAEC(L) = 1 ppm ai (0.09 mg ai/kg bw/day) based on ≥ 50% inhibition in female plasma levels Range of dose per body weight reflects weights of study animals (male and female)

[1]Range is 95% confidence interval.
[2] It is uncertain if test concentrations were adjusted for purity of the test material.
NA = not applicable
– See DERs for more complete explanations of study classifications.

Table C-4. Summary of Toxicity of Terbufos to Terrestrial Plants

Species	Exposure Scenario	% AI	Toxicity	MRID	Toxicity Category	Classification
Cabbage, Carrot, Cucumber, Lettuce, Soybean, Tomato, Corn, Oat, Onion, and Ryegrass	Tier 1 Seedling Emergence	89.3	EC_{25} >2.04 lb ai/A (m) NOAEC = 2.04 lb ai/A Applies to monocots and dicots	48710801	NA	Supplemental (tested TGAI instead of TEP and tested fewer than the minimum recommended number of seeds per treatment level)

m = measured; NA = not applicable
– See DER for more complete explanations of study classifications.

Appendix D: Summary of Mixture Toxicity Data

Table D-1. Summary of Open Literature Studies on Toxicity of Mixtures[1] of Terbufos and Other Pesticides[2]

Citation	Chemicals tested[1]	Test species	Summary[3]
Baerg, 1994	Terbufos, Terbufos Sulfone, Nicosulfuron, Chlorimuron, Bentazon, Imazethapyr, Malathion, and Cinnamic Acid	Corn	Terbufos inhibited nicosulfuron metabolism in corn. Terbufos sulfone inhibited the metabolism of nicosulfuron and imazethapyr but not bentazon in corn. Terbufos sulfone inhibited P450 activity; that is, the hydroxylation of nicosulfuron, chlorimuron, bentazon, and imazethapyr (but not cinnamic acid) and the desulfuration of malathion in corn.
Biales et al., 2011	Terbufos and Permethrin	Fathead minnow	Increased mortality was observed in the mixture compared to only terbufos or permethrin exposure. Twenty-four proteins were found to be differentially expressed among all three treatments (mixture, only terbufos, and only permethrin).
Castro-Escobar et al., 1996	Terbufos, Nicosulfuron, and Primisulfuron	Corn (*Zea mays*)	Corn injury from nicosulfuron and primisulfuron increased with an increased application rate of terbufos. Plant height following application of nicosulfuron and primisulfuron showed an inverse relationship with increased application rate of terbufos (i.e., plant height decreased with increased terbufos rate).
Choung et al., 2011a	Terbufos sulfone and Atrazine	Southern Bell Frog	The authors concluded that atrazine did not interact synergistically with terbufos sulfone. Terbufos sulfone alone and as a mixture significantly slowed larval development and ultimately delayed metamorphosis.
Choung et al., 2010	Terbufos, Terbufos sulfone, Terbufos sulfoxide, and Atrazine	*Chironomus tepperi*	No interaction was observed between atrazine (25 µg/l) and mixtures with either terbufos, terbufos sulfone, or terbufos sulfoxide.
Choung et al., 2011b	Terbufos, Terbufos sulfone, Terbufos sulfoxide, and Atrazine	*Ceriodaphnia dubia*	The addition of atrazine (10 µg/l) significantly increased the toxicity of terbufos. The toxicity of terbufos sulfone was unaffected by atrazine, whereas the results for terbufos sulfoxide were equivocal.
Diehl et al., 1995	Terbufos and Nicosulfuron	Corn (*Zea mays*)	Fresh corn weight was reduced more from exposure to a mixture of terbufos and nicosulfuron than to exposure of either terbufos or nicosulfuron alone. Plant metabolism of nicosulfuron was slowed by the presence of terbufos.

Citation	Chemicals tested[1]	Test species	Summary[3]
Diehl and Stoller, 1995	Terbufos and Nicosulfuron	Corn (*Zea mays*)	Terbufos, applied to the soil at planting, interacted with nicosulfuron applied postemergence to injure corn and reduce grain yield. No visual injury or yield reductions were noted in corn treated with nicosulfuron alone. The terbufos 15G formulation caused greater corn injury than did the Counter 20CR (terbufos) formulation at each rainfall timing when sprayed with nicosulfuron.
Downard et al., 1999	Terbufos, Trisulfuron, Desmedipham, and, Phenmedipham	Sugar beet (*Beta vulgaris)*	In some cases toxicity to sugar beet (% injury) was significantly increased when plants were exposed to terbufos + trisulfuron and terbufos + trisulfuron + desmedipham + phenmedipham compared to exposure to individual chemicals or the herbicides mixture. The impact of the mixture (enhanced toxicity or no effect vs exposure to individual chemicals or herbicide mixtures) varied by factors including experimental site location and year, pesticide application concentration, terbufos formulation, and terbufos application method. Mixtures did not increase adverse effects on population number, root yield, sucrose content, or extractable sucrose. Exposure to terbufos + desmedipham + phenmedipham did not result in enhanced or decreased toxicity to any measured endpoint. In a few cases, exposure to terbufos + herbicide(s) increased root yield, sucrose content, and/or extractable sucrose.
Foster and Brust, 1995	Terbufos and Methyl bromide	Watermelon *citrullus lanatus*; striped and spotted cucumber beetle	Watermelon growth and yield were similar in terbufos only treatments and controls. Exposure to a mixture of methyl bromide and terbufos resulted in similar watermelon growth and yield as exposure to methyl bromide alone.
Frazier and Nissen, 1994	Terbufos, Benoxacor, CGA-185072, MON-13900, and Primisulfuron	Corn (*Zea mays*)	Exposure to a mixture of primisulfuron and terbufos reduced shoot dry weight and shoot length compared to the negative control and either compound alone. Preemergence applications of the safeners CGA-185072 and MON-13900 significantly reduced stunting effects on corn from the combined exposure to primisulfuron and terbufos; however, shoot weight and length remained reduced compared to the negative control. Benoxacor had no safening effect.
Green and Ulrich, 1994	Terbufos and Rimsulfuron	Corn (*Zea mays*; inbred and hybrid varieties)	Terbufos applied with rimsulfuron significantly reduced growth (weight) in three of four varieties of corn compared to exposure to either compound alone.
Hein and Wilson, 1995	Terbufos, Cycloate, Ethofumesate, and Diethatyl	Sugar beet	Yields decreased when terbufos was applied with cycloate treated plots. On ethofumesate and diethatyl treated plots, root yield also decreased.
Holshouser et al., 1991	Terbufos and CGA-136872 (sulfonylurea herbicide)	Corn (five hybrids)	All hybrids showed increased injury and reduced yield after CGA-136872 was applied in combination with terbufos (in-furrow application). Injury increased with increased application rate of CGA-136872.

Citation	Chemicals tested[1]	Test species	Summary[3]
Kapusta and Krausz, 1992	Terbufos and Nicosulfuron	Corn (*Zea mays*)	Terbufos applied in-furrow at planting interacted with nicosulfuron applied post to cause significant injury 25 to 60 days after planting in 1989 and 1990. Injury decreased significantly when nicosulfuron was applied at later growth stages of corn. Plant population was not affected by the combined exposure to terbufos and nicosulfuron. Corn ear number and grain yield in 1989 and 1990 were lower in plots treated with terbufos at planting and nicosulfuron applied at the three leaf stage than in plots treated with only nicosulfuron. There were no differences in the height of corn, ear number, or grain yield when nicosulfuron was applied at the seven-leaf stage regardless of terbufos application in 1989 and 1990.
Kwon et al., 1995	Terbufos, Nicosulfuron, Primisulfuron, and Piperonyl butoxide (PBO)	Corn (six hybrids)	Toxicity to corn (reduced height and/or increased % injury) increased when plants were exposed to terbufos + nicosulfuron, terbufos + primisulfuron, terbufos + nicosulfuron + PBO, and terbufos + primisulfuron + PBO compared to toxicity of single chemicals. Toxicity of terbufos + PBO was not enhanced compared to toxicity of each chemical alone.
Kwon, 1993	Terbufos, Metolachlor, Alachlor, Acetochlor, Chlorimuron, Nicosulfuron, Primisulfuron, Imazaquin, and antidotes (CGA-154281 and naphthalic anhydride)	Corn	Toxicity to corn (reduced height and/or increased % injury) was increased when plants were exposed to terbufos + chlorimuron, terbufos + nicosulfuron, terbufos + primisulfuron, terbufos + chlorimuron + metolachlor, terbufos + nicosulfuron + metolachlor, terbufos + primisulfuron + metolachlor, terbufos + chlorimuron + metolachlor + CGA-154281, terbufos + nicosulfuron + metolachlor + CGA-154281, terbufos + primisulfuron + metolachlor + CGA-154281, terbufos + nicosulfuron + naphthalic anhydride, and terbufos + primisulfuron + naphthalic anhydride compared to toxicity of each chemical (or combination of chemicals when applicable) alone. Toxicity to corn from exposure to terbufos + metolachlor, terbufos + alachlor, terbufos + imazaquin, terbufos + imazaquin + metolachlor, and terbufos + imazaquin + metolachlor + CGA-154281 was not enhanced compared to toxicity of each chemical (or combination of chemicals when applicable) alone. Toxicity to corn from exposure to terbufos + acetochlor was reduced compared to exposure to acetochlor alone (only at the 6.7 kg/ha acetochlor application rate). Toxicity of terbufos + primisulfuron was the same as that of primisulfuron alone for barnyard grass, giant foxtail, and velvetleaf.

Citation	Chemicals tested[1]	Test species	Summary[3]
Langton, 1997	Terbufos, Flumetsulam, Clopyralid, 2,4-D, Rimsulfuron, Thifensulfuron, Halosulfuron, Safener, Prosulfuron, Primisulfuron, and Nicosulfuron	Corn	Significant interactions between terbufos and other chemicals were observed in terms of effects on corn (height, yield, and stand) after exposure to mixtures of terbufos + flumetsulam, terbufos + nicosulfuron, terbufos + flumetsulam + nicosulfuron, terbufos + flumetsulam + nicosulfuron + pyrimisulfan, and terbufos + rimsulfuron + thifensulfuron. Terbufos did not show significant interactions in any other combinations of tested chemicals (terbufos + prosulfuron + primisulfuron, terbufos + halosulfuron + safener, terbufos + halosulfuron, and terbufos + flumetsulam + clopyralid + 2,4-D).
Lentz et al., 1985	Terbufos and Metribuzin	Soybean	Treatments of terbufos when combined with metribuzin produced significantly greater injury and reduced yield than when metribuzin or terbufos was applied alone.
Messaad et al., 2000	Terbufos and Atrazine	Red shiner minnow (*C. Lutrensis*)	Generally, thermal tolerance of red shiner after exposure to atrazine, terbufos, or a mixture of both compounds decreased at both test temperatures compared to the control. Thermal tolerance was measured as the critical thermal maximum response method (CTM). There was a possible additive effect of the mixture observed at the highest test temperature/mixture concentration combination.
Messaad, 1996	Terbufos and Atrazine	Red shiner minnow (*C. Lutrensis*)	Overall survival was lowest for the pesticide mixture (92% at 23°C and 48% at 30°C) in comparison to atrazine only at 30°C (54%), terbufos (97% at 23 °C and 91% at 30 °C) or the control (100%).
Morton, 1993	Terbufos and Nicosulfuron	Field and sweet corn (*Zea mays*)	Exposure to nicosulfuron and terbufos increased plant injury and tiller formation and decreased yield and height compared to exposure to either compound alone. The toxicity of the mixture varied and was a function of many factors including application rate, application timing (nicosulfuron), terbufos formulation and method of application, effect endpoint, and experimental site location. Toxicity of the mixture was not enhanced in all cases.
Morton et al., 1994	Terbufos and Nicosulfuron	Corn (*Zea mays*)	In two of three locations, vigor was reduced more when corn was exposed to both nicosulfuron and terbufos compared to nicosulfuron or terbufos alone. Similarly, grain yield was reduced more by the mixture in some of the experimental groups at one of the locations.
Noetzel and Kellesvig, 1993	Terbufos and Carbofuran	Canola (*Brassica napus*)	The combination of terbufos and carbofuran did not impact toxicity to canola compared to that of each chemical alone.

Citation	Chemicals tested[1]	Test species	Summary[3]
Rahman and James, 1993	Terbufos and Nicosulfuron	Corn (*Zea mays*)	Damage to corn increased with increasing exposure to nicosulfuron and varied by terbufos application method; damage was greater when terbufos was applied in an open furrow or as a 17-cm band with or without incorporation. Despite phytotoxic effects, all plants recovered within 4 weeks. Exposure to terbufos and nicosulfuron had no effect on crop yield or crop maturity compared to exposure to nicosulfuron alone.
Simpson et al., 1994	Terbufos, Nicosulfuron, and 2,4-D	Corn (*Zea mays*)	Exposure to nicosulfuron and terbufos caused increased visual injury and reduced dry weight. Exposure to 2,4-D and terbufos did not result in an obvious increase in visual injury or reduce dry weight. Exposure to 2,4-D, nicosulfuron, and terbufos decreased the degree of visual injury and amount of reduction in dry weight caused by the nicosulfuron/terbufos interaction. The timing of the 2,4-D application relative to the nicosulfuron application impacted the safening effect on the nicosulfuron/terbufos interaction.
Smart and Bradford, 1995	Terbufos, Prosulfuron, and Atrazine	Corn and Sorghum	The mixture of prosulfuron and terbufos increased effects on corn height, injury, and leaf stage but not yield. The mixture of atrazine and terbufos did not impact effects on corn. Irrigated sorghum yield was reduced by exposure to prosulfuron and terbufos but not to atrazine and terbufos compared to a no herbicide control. Irrigated sorghum height and leaf stage were also impacted by the prosulfuron and terbufos mixture.
Tien and Chen, 2012	Terbufos, Chlorpyrifos, and Methamidophos	Diatom (*Nitzschia* sp.), cyanobacteria *Oscillatoria* sp., and chlorophyta *(Chlorella* sp.)	The EC_{50} values for the pesticide mixtures (terbufos + chlorpyrifos, terbufos + methamidophos, and terbufos + chlorpyrifos + methamidophos) were mostly higher than those for single pesticides (antagonistic effect). Only one mixture (terbufos + methamidophos) showed a synergistic effect and that effect was on a multiple algal species assemblage; in contrast this chemical mixture had an antagonistic effect on single species of algae.
Waldrop and Banks, 1983	Terbufos, Acifluorfen, Toxaphene, BAS-9052, Metribuzin, Metolachlor, and Oryzalin	Soybean (*Glycine max*)	Effects from exposure to terbufos plus either acifluorfen, toxaphene, BAS-9052, or metolachlor were not significantly different from those due to exposure to the individual compounds. Exposure to terbufos plus either metribuzin or oryzalin caused increased toxicity (increased injury, decreased shoot and root weights, and/or decreased yield) compared to exposure to the individual compounds. Increased effects due to the mixture were observed for metribuzin in both greenhouse and field (2 years) experiments whereas they were observed for oryzalin in greenhouse but not field experiments.

[1] The term "mixture" used in this table means that the test species was exposed at some point during the experiment to terbufos and one or more other pesticides. It does not necessarily mean that the chemicals were applied simultaneously. For example, terbufos may have been applied to the soil followed by a foliar application of an herbicide.

[2] This review focuses on chemicals that were tested as mixtures with terbufos. In some cases additional chemicals were tested but not in combination with terbufos; these chemicals are not reported here.

[3] The summary focuses on potential interactions between terbufos and other chemicals and is not intended to be a comprehensive detailing of all results.

Appendix E: Incident Data

Table E-1. Terbufos Aquatic Incidents (EIIS)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Unknown[1]	2003	IN	50-60 300-400 Over 2000	Bass Bluebird Crappie	**Probable**. The fish kill occurred on May 8, 2003 in a pond in Grant County, IN. Terbufos (Counter CR) was thought to be involved. It was reported that terbufos was present in the pond. It was also reported that a residue of 1.46 ppm was detected but the compound was not specified. (I013987-001)
Unknown[1]	2003	IN	120 4400 6000	Bass Bluegill Crappie	**Possible.** The fish kill occurred on April 22, 2003 in two ponds in Grant County, IN. The granular Counter CR formulation of terbufos had been applied a nearby field. Terbufos and its "toxic degradates" (undefined) were detected in both ponds at concentrations > 2 ppb. (I014116-001)
Corn	2000	IN	650 100 200 200	Bluegill Bass Catfish Crappie	**Highly Probable.** The fish kill occurred from June 16, 2000 to June 17, 2000 in a pond adjacent to a corn agricultural area in Ohio County, IN. Terbufos (Counter) had been applied to a corn on a nearby field. Terbufos sulfoxide (3.4-5.1 ppb) and terbufos sulfone (1.8-3.6 ppb) were detected in the pond 34 days after application to the field. The legality of the incident is misuse or accidental. (I010477-002)
Corn	2000	IN	4000 300 40 Few	Bluegill Bass Catfish Crappie	**Highly Probable.** The fish kill occurred on May 16, 2000 in a pond adjacent to a corn agricultural area in Montgomery County, IN. Terbufos (Counter) had been applied to a corn on a nearby field. Terbufos sulfoxide (12-21 ppb) and terbufos sulfone (1.28 ppb) were detected in the pond 23 days after application to the field. The legality of the incident is misuse or accidental. (I010477-001)
Corn	1998	NE	180 20	Bluegill Catfish	**Highly Probable.** The fish kill occurred in a 1 acre farm pond in Nebraska (location not given). Terbufos had been applied to a corn field 23 days earlier; there was a slope of 15% in the field. Terbufos was not detected in the water but 5 days after the incident the concentration of terbufos sulfoxide was 15.5 ppb and terbufos sulfone was 6.6 ppb. (B0000-506-02)
Corn	1998	IN	300	Bluegill	**Highly Probable.** The fish kill occurred in a pond in a field near Greensburg, IN. Terbufos was not detected in the water but water concentrations of 20.8 to 22.7 ppb of terbufos sulfoxide and sulfone were detected 2 days after the incident. Water concentrations of 1.2-1.3 ppb of terbufos sulfoxide were detected 47 days after the incident. (B0000-506-01)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1998	IN	10000 3000 100 200	Bluegill Largemouth Bass Catfish Walleye	**Possible.** The fish kill occurred on June 19, 1998 in a 15 acre, 20 foot deep farm pond in Lagro, IN. The grower applied the CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A to a 75 acre corn field. The "field drains into neighbor's farm pond and pond overflows into reported pond incident". Analysis of water samples revealed no evidence of terbufos residues. (I007795-0021)
Corn	1998	IN	2000-3000 500	Bluegill Largemouth Bass	**Possible.** The fish kill occurred on June 19, 1998 in a farm pond in Lagro, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A to a 75 acre corn field. The field drains via tile into the farm pond. There is also a 2 to 3 foot deep drainage ditch that carries runoff into the pond. Analysis of water samples revealed no evidence of terbufos residues. (I007795-001)
Corn[1]	1998	IN	2400 20 10 1	Bluegill Bass Frog Carp	**Probable.** The fish kill occurred on June 18, 1998 in a farm pond in Huntington, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A to a 46 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007676-001)
Corn[1]	1998	IN	>5000	Bluegill Bass Catfish Minnow Crappie	**Probable.** The fish kill occurred on June 13, 1998 in a 2 acre farm pond in LaFountaine, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A to a 76 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-006; I007513-006)
Corn[1]	1998	IN	1400	Fish	**Probable.** The fish kill occurred on June 13, 1998 in 2 farm ponds in Lewis, IN. The grower applied the 20CR formulation of terbufos as a T-banded application at planting at the labeled rate. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-005; I007513-005)
Corn[1]	1998	IN	~1100 50-75 200	Bluegill Bass Crappie	**Probable.** The fish kill occurred on June 14, 1998 in a 3 acre farm pond in Wabash, IN. The grower applied the 20CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A. Mortality estimates for bluegill ranged from 1000- 1200. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-004; I007513-004)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn[1]	1998	IN	1000 100 50	Bluegill Bass Walleye	**Probable.** The fish kill occurred on June 16, 1998 in a 2 acre farm pond in Wabash County, IN. The grower applied the CR formulation of terbufos as a T-band application at planting. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-003; I007513-003)
Corn[1]	1998	IN	5100 100	Bluegill Bass	**Probable.** The fish kill occurred on June 13, 1998 in 2 farm ponds in Chester, IN. The grower applied the CR formulation of terbufos as an in-furrow application at planting at the rate of 1.3 lb ai/A to a 38.5 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-002; I007513-002)
Corn[1]	1998	IN	60 32 1	Bluegill Bass Catfish	**Probable.** The fish kill occurred on June 16, 1998 in a 0.8 acre farm pond in Wabash, IN. The grower applied the CR formulation of terbufos as a T-band application at planting at the rate of 1.3 lb ai/A to a 74 acre field. Analysis of water samples revealed terbufos sulfoxide and terbufos sulfone residues. (I007924-001; I007513-001)
Banana plantation	1997	Philippines	NR	Fish	**Probable.** The fish kill occurred on January 1, 1997 on agricultural land in the Philippines. Mortality may be linked to runoff of multiple pesticides, including the granular form of Counter 10G. (I006395-001)
Corn[1]	1997	Corn belt	NR	Fish	**Possible.** American Cyanamide reported 5 fish kill incidents involving farm ponds in Indiana, Nebraska, and possibly other corn belt states in 1997. (I006718-001)
Corn[1]	1996	Corn belt	NR	Fish	**Possible.** American Cyanamide reported 1 fish kill incident in the corn belt in 1996. (I004607-001; I006718-001)
Corn[1]	1995	Corn belt	NR	Fish	**Possible.** American Cyanamide reported 4 fish kill incidents involving farm ponds in the corn belt in 1995 (I002814-001; I006718-001)
Corn[1]	1994	Corn belt	NR	Fish	**Possible.** American Cyanamide reported 7 fish kill incidents involving farm ponds in the corn belt in 1994 (I002814-001; I006718-001)
Corn	1994	NC	100	Bass Bluegill Crappie	**Probable.** On May 10, 1994, the North Carolina Department of Agriculture reported a fish kill incident involving approximately 100 fish that occurred in a canal that fed into the Pasquotank River in Pasquotank County. Terbufos (Counter CR) had been applied to a corn field adjacent to the canal. Residue analysis revealed 140 ppb of terbufos in the canal. (I003826-025; IR94-51; North Carolina Department of Agriculture)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1994	LA	1386	Fish	**Probable.** Terbufos and permethrin applied preplant to 3769 acres of corn. The Louisiana State University Medical Diagnostic Laboratory concluded that the fish were killed by terbufos and permethrin. (I001849-003; I001179-20)
Corn[1]	1993	Corn belt	NR	Fish	**Possible.** American Cyanamide reported fish kill incidents at 14 farm ponds in the corn belt in 1993. (I002814-001; I006718-001)
Corn	1993	NC	15 15	Bass Bream	**Highly Probable.** A fish kill occurred in Clinton, NC (Sampson County) on April 6 following application of atrazine and terbufos to a neighboring corn field approximately 365 feet away. Water samples taken a week later revealed 2 ppb of terbufos. No analyses were conducted on the dead fish. (I003654-003)
Corn[1]	1992	Corn belt	NR	Fish	**Possible.** American Cyanamide reported 2 fish kill incidents in the corn belt in 1992 (I002814-001; I006718-001)
Corn tobacco	1992	NC	Small number	Bluegill	**Possible.** A fish kill in a small pond adjacent to tobacco and corn fields in North Carolina on June 12, 1992. Terbufos, carbofuran, and aldicarb were applied to adjacent fields. (I000165-052)
Banana	1992	Costa Rica	1250 300	Fish Tilapia	**Probable.** Moribund fish were discovered in a river adjacent to a terbufos-treated banana farm. Other pesticides had also been used in the area. According to the report terbufos was suspected as being responsible for the fish kill. (I000286-001)
Corn[1]	1991	IA	NR	Fish	**Probable/Misuse.** Grower in Fontanelle, Adair County, IA, reportedly left a partially used bag of Counter® 15G eight feet from pond. (B000170-6; I002814-002)
Corn	1991	IA	4000-5000	Bluegill Crappie Small Bass	**Probable.** This incident involved 6 ponds in Chariton, Lucas County, IA. Residue analysis 2 to 4 weeks after treatment showed 1-4 ppb terbufos sulfoxide in the pond. (B000170-4; I002814-002)
Corn	1991	IA	large number	Bluegill Bass Crappie Catfish	**Probable.** Fish kill occurred on June 9 in several ponds east of Chariton, IA. The largest pond (3.5 acres) was surrounded by 300-1000 feet of pasture/grassy buffer strip. Terbufos was applied as a banded application on an adjacent farm. Terbufos residues (1 ppb) recovered from pond water on July 6. No analyses made on dead fish. (B000300-41)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1991	IA	500 400 3	Bluegill Bass Snapping Turtle	**Probable.** Fish kill occurred in 2 ponds in Milo, Warren County, IA. Incident is related to a study by Wildlife International. Pond was surrounded by grassy strips and steep sloped corn fields. Terbufos also caused a fish kill in these ponds in 1990. (B000170-005; I002814-002)
Corn	1991	IA	NR	Fish	**Possible.** A pond near corn field in Lucas County, IA experienced a fish kill in June, 1991. No residue analysis was performed. (I000254-002: Submitted by Region VII)
Corn	1991	IA	NR	Bluegill Bass Crappie Catfish	**Highly Probable.** Pond near corn field in Lucas County, IA experienced fish kill in June, 1991. Residue analysis revealed terbufos in water following kill and 3 weeks later. Trifluralin and Bicep also applied. (I000254-001: Submitted by Region VII)
Corn	1991	IL	1000	Bluegill	**Probable.** Pond in Nashville, Washington County, IL experienced a fish kill. An assay conducted 2 weeks after treatment revealed 3 ppb terbufos sulfoxide. (I002814-002; I000170-001)
Corn	1991	IL	41800 38000 6318 4343	Bluegill Bass Sunfish Crappie	**Highly Probable.** On May 4, 1991, terbufos was applied at a rate of 1.3 lb ai/A on a no-till corn field adjacent to Taylor Lake, in Victoria, IL (Knox County). Taylor Lake is a former strip mine. A total of 90,461 fish were found dead. The species affected included bluegill, largemouth bass, green sunfish, black crappie, red-ear sunfish, and hybrid sunfish. The dead sunfish had the pectoral fin in the forward position across the head: which is considered to be a sign of OP toxicosis. An assay conducted 2 weeks after treatment revealed 2 to 9 ppb terbufos sulfoxide. (I005002-003; B000166-001; I002814-002; I000170-2; Illinois Department of Conservation,1991)
Corn	1991	IN	1500	Bluegill Crappie	**Possible.** Incident occurred in Whiteland, Brown County, IN involving 1500 bluegill and crappie fingerlings. No assay was conducted. (I002814-002; I000170-003)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn Tobacco	1991	NC	200+	Bluegill Bass	**Possible.** On May 10, 1991, a fish kill occurred in Onslow, North Carolina. Terbufos, disulfoton, ethoprop, chlorpyrifos, atrazine, and napropamide were applied to adjacent corn and tobacco fields. Analysis of pond water and surrounding soils found terbufos, chlorpyrifos, napropamide, and atrazine residues. Because the chlorpyrifos and terbufos residues were higher than napropamide and atrazine residues, they were considered more likely to have caused the kill. The crops that were associated with the fish kill were corn and tobacco. Terbufos was applied to the corn crop only. A corrugated pipe connects the fields to a drainage ditch and a concrete pipe to connect the ditch and runs under the road to the pond. Apparently pesticide application was applied too close to the water. (I000799-004; IR91-60 North Carolina Department of Culture)
Corn or Sorghum	1991	TX	NR	Fish	**Possible.** Incident occurred on April 19, 1991 in a lake adjacent to a 500 acre treated field in Lamar, Texas. Assay of water samples was negative. Crop listed in report as field crop/grain with the pest as greenbug. (I00917-004· TDA incident No. 11-91-0017)
Corn	1990	IA	300	Bluegill	**Probable.** Event occurred in Audubon County, IA. Terbufos sulfoxide found in residue analysis. (B000168-002; I002814-003)
Corn	1990	IA	200	Bluegill	**Probable.** Event occurred in Audubon County, IA. Terbufos sulfoxide found in residue analysis. (B000168-001; I002814-003)
Corn	1990	IA	200+	Bluegill	**Probable.** Event occurred in Montgomery County, IA. Field sloping towards pond. Terbufos sulfoxide found in residue analysis. (B000168-003; I002814-003)
Corn	1990	IA	200+	Bluegill	**Probable.** Event occurred in Warren County, IA. Terbufos sulfoxide found in residue analysis. (B000168-006; I002814-003)
Corn	1990	IA	200+	Bluegill	**Probable.** Event occurred in Milo, Warren County, IA. Incident is related to a study by Wildlife International. Terbufos sulfoxide found in residue analysis. (B000168-005)
Corn	1990	IA	500	Bluegill	**Possible.** Event occurred in Washington County, IA. No residue samples taken. (B000168-004; I002814-003)
Corn	1990	IA	200+	Bluegill	**Probable.** Event occurred in Warren County, IA. Terbufos sulfoxide found in residue analysis. (B000168-006; I002814-003)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1990	IL	150	Bluegill	**Possible.** Event occurred in Coles County, IL. No residue samples taken. (B000168-013; I002814-003)
Corn	1990	IL	10000-15000	Fish	**Possible.** Event occurred in McHenry County, IL. No residue samples taken. (B000168-014)
Corn	1990	IL	NR	Bluegill	**Probable.** Event occurred in Du Page County, IL. Terbufos found in residue analysis. (B000168-015)
Corn	1990	IL	20	Bluegill	**Probable.** Event occurred in St Clair County, IL. Terbufos sulfoxide found in residue analysis. (B000168-0016)
Corn	1990	KS	300	Fish	**Probable.** Event occurred in Leavenworth County, KS. Terbufos was applied in furrow. Terbufos sulfoxide found in residue analysis. (B000168-007)
Corn	1990	MI	500-600	Bluegill	**Probable.** Event occurred in Hillsdale County, MI. Terbufos was applied as a banded application. Terbufos sulfoxide found in residue analysis. (B000168-008)
Corn	1990	OH	100 % in 4-5 acre pond	Bass, Bluegill Catfish Crappie Snake	**Probable.** On May 15, 1990, bass, bluegill, catfish, crappie, and a black snake were reported killed from the use of terbufos applied in-furrow at-planting on a corn field at a rate of 1.3 lb ai/A in Licking County, Ohio. The Ohio Department of Agriculture measured terbufos residues of 10 ppb. Ammonia, atrazine, and metolachlor residues were also found. The investigator concluded that the kill could have been caused by terbufos or ammonia. The total kill was reported for the 4 to 5-acre pond that was 5 to 6 feet deep (B000168-12; 422059-01; American Cyanamid, 1992)
Corn	1990	OH	NR	Bluegill	**Probable.** Event occurred in Clinton County, OH. Terbufos was applied as a banded application. Terbufos sulfoxide found in residue analysis. (B000168-010)
Corn	1990	OH	1500-1800	Bluegill	**Possible.** Event occurred in Darke County, OH. Terbufos was applied as a banded application. There was no residue analysis performed. (B000168-011)
Corn	1990	OH	10000-15000	Bluegill	**Probable.** Event occurred in Licking County, OH. Terbufos was applied as an in furrow application. Terbufos sulfoxide found in residue analysis. (B000168-009)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn[1] Sorghum[1]	1990	TX	200	Fish	**Probable.** Incident occurred in Bell County, Texas. Investigators suspect that runoff from the neighbors field into tank caused the fish to die. Samples of fish analyzed contained terbufos. Crop listed in report as field crop/grain. Corn and sorghum are the most likely crops to have been involved. Metalochlor, 2,4-D, atrazine, and picloram were also applied to adjacent fields. (I00917-003; TDA incident No. 05-90-0034)
Corn	1989	NC	600 12	Small Fish Crayfish	**Highly probable.** On May 5, 1989, a fish kill occurred from the use of Counter 15G on a nearby corn field in Sampson County, NC. About 600 small fish and 12 crayfish were found dead in an adjacent water body. The corn field was treated on April 20. The metabolite of terbufos, terbufos sulfone, was detected in the water samples. (B000169-001; IR89-40. North Carolina Department of Agriculture 1989)
Corn	1989	NC	2000+	Fish	**Highly probable.** On April 30, 1989, thousands of fish were killed in a canal which feeds into the Alligator River following the application of terbufos 15G and alachlor to corn in Tyrell County, NC. By the time the fish kill was investigated on May 1, 1989, the fish had drifted into the Alligator River. Terbufos had been applied in-furrow at-planting and alachlor on top after planting. Terbufos sulfone, the metabolite of terbufos, was detected in soil samples. (B000164-001; R89-37. North Carolina Department of Agriculture, 1989)
Corn	1989	NC	400	Fish	**Highly probable.** On May 16, 1989, about 400 fish died from the use of Counter 15G. Terbufos was measured in the water samples taken in a pond adjacent to a field that was treated with terbufos on corn. An adjacent tobacco field had been treated with ethoprop and pebulate, but no measurable residues were detected for those chemicals. (B000167-001; IR89-44. North Carolina Department of Agriculture, 1989)
Corn	1985	NE	1000	Fish	**Possible.** Terbufos was applied in a corn field in Butler County, NE on May 8, 1985. The water source for this pond was filtered overflow from a larger pond which had also suffered a fish kill at the same time. Terbufos (applied in-furrow to corn) and phorate (applied to sorghum) had recently been used in nearby fields above the pond. (I000598-001A; Nebraska Game and Parks Commission, 1985).
Corn[1]	1985	NE	"many"	Fish	**Possible.** In 1985, terbufos was applied in a field near a pond in Richardson County, NE. (I000598-007, Nebraska Game and Parks Commission)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1984	SC	100 100	Bass Bream	**Possible.** On April 2, 1984 a fish kill was reported in Williamsburg County, SC. Terbufos, atrazine, and metalochlor were used on the adjacent corn field 2 to 3 days before the kill. Analysis of a water sample showed no terbufos residues but tested positive for atrazine and metalochlor. (B000163-001)
Corn	1981	MO	NR	Fish	**Possible.** Fish kill occurred on May 29, 1981 in Krueger Pond, Lafayette County, MO (near the town of Alma). A one acre pond was affected. Butylate and atrazine were also applied to the corn field. (B000165-001; I000636-032)
Corn	1981	MO	NR	Bluegill Crappie	**Possible.** On June 3, 1981, terbufos was implicated in a Missouri fish kill with multiple pesticide use (atrazine, Sutan and terbufos). Many small bluegill and a few crappie reportedly were affected from the use on corn. (Missouri Department of Conservation, 1981)
Corn	1978	IA	many	Fish	**Possible.** Terbufos was applied in a corn field in Iowa in 1978. Runoff into a farm pond drained about ½ acre of the treated corn field. Many dead fish were found in the pond. (Pesticide Incident Monitoring System, 1981)
Unknown[1]	1976	IL	20	Bluegill	**Possible.** Around April 1976, terbufos was applied to a field across the road from a 0.8 acre pond in Illinois. About 20 dead bluegill were found. Laboratory work did not confirm the presence of terbufos. (Pesticide Incident Monitoring System, 1981)

[1] Crop association, if any, is uncertain.

*Some incidents were linked to specific formulations (Counter 15G and CR). The Counter 20G formulation was not specifically linked to any incidents.

NR = not reported

NOTE: hundreds interpreted as 200+; thousands as 2,000+
soil incorporated interpreted as in-furrow application
surface application interpreted as banded application

Table E-2. Terbufos Terrestrial Incidents (EIIS database)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Unknown[1]	2008	KS	1 87 55 47	Mallard White-fronted goose Canada goose Goose	**Possible.** Incident occurred in Rice, KS starting on December 16, 2008 and ending on December 23, 2008. This mortality was out of approximately 10,000 geese that were using the 20-acre refuge area on private ground. Two Canada geese, two Cackling geese, one White-fronted goose, and one Mallard were analyzed. Salt toxicosis was determined to be the cause of death in one Canada goose, one Cackling goose, and one White-fronted goose. Terbufos was detected in the gizzard content of one of the White-fronted geese. Strychnine was detected in a Mallard duck. (I020995-002)
Unknown[1]	2002	NC	5	Red wolf	**Possible.** Incident occurred in Hyde, NC starting on March 9, 2002 and ending on March 14, 2002. Cause was diagnosed as toxicosis by terbufos plus scabies infection. (I018980-007)
Unknown[1]	2001	NJ	1	Cooper's Hawk	**Highly Probable.** Incident occurred in Burlington County, NJ on May 2, 2001. A necropsy showed that its brain cholinesterase activity was reduced 78% below normal, and the stomach contents (bird remains and two wheat seeds) had 61.8 ppm terbufos. The conclusion was that terbufos was the cause of death, but there was no determination of the source of the terbufos. (I012549-007)
Corn	1997	DE	2	Canada geese	**Highly Probable.** Incident occurred in Felton, DE (Kent County) on May 27, 1997 in a 7 acre stand of field corn. The geese were feeding in the newly planted corn which had been treated with Counter 15G. There were heavy rains prior to the incident. Analysis of the stomach contents revealed 75 ppm of terbufos. (I007372-001)
Misuse	1996	Canada	NR	Eagles	**Probable/Misuse.** Carcasses baited with terbufos for coyote control in Saskatoon area of Canada. (I004605-001; references newspaper article in Star Phoenix)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Corn	1996	TX	20	Swainsons hawks	**Highly Probable/Misapplication**. An incident in occurred on April 27, 1996 near Dumas, Texas (King County) in which about 20 migrating Swainson's hawks were killed by terbufos (Counter 15G). The registrant commissioned a team of scientists to conduct an assessment of the incident. The unpublished report developed by that team has been reviewed by the Agency. The report draws the following conclusions: The hawks were killed while gorging on grubs (larvae of the Southern masked chafer) exposed in a newly plowed field. Stomach contents were found to contain soil, grubs, and terbufos residues ranging from 6.5 to 16 ppm. The exposure of the birds to terbufos resulted from failure to cover the furrows after plowing. The furrows were not properly covered because of equipment failure associated with plowing under unusually wet soil conditions. In much of the field, the corn seed and the terbufos granules were deposited on to the soil surface instead of inside the furrow. The dead hawks were discovered 7 days after planting. The conclusion of the report is that the incident occurred under an unusual set of conditions. (I003498-001; I006435C)
Corn[1]	1995	WI	2	Red-tailed hawk	**Highly Probable**. An adult female and a hatchling red-tailed hawk were found at the base of a tree in Madison, WI. Meat taken from the crops of the hawks contained 12 and 13 ppm terbufos. The investigator speculated that the prey of the hawks had been a rodent from a nearby corn field. (I002993-012; I002733-043, USFWS case file 2300)
Unknown[1]	1994	Canada	4	Bald eagles	**Highly Probable/Possible Misuse**. An incident occurred in Vancouver, British Columbia involving 4 eagles. Analysis of the contents of the crop and stomach confirmed the presence of terbufos and its oxidative degradates at levels that could have caused the death of the eagles. Misuse is suspected because the eagles were found many months after the normal application time for terbufos and the significant amounts of terbufos (relative to the amounts of oxidative degradates). (I002486)
Unknown[1]	1994	NC	2	Red wolf	**Highly Probable/Misuse**. Two dead red wolves were found near a farm in NC in the Fall of 1994. Analysis of the stomach contents revealed "large quantities" of terbufos (38 ppm), rabbit flesh, and shotgun pellets. The presence of these 3 items in the gut strongly supported a case of intentional poisoning. The wolves had been introduced by the U.S. Fish and Wildlife Service against the wishes of the owners of the farm. (I002484)

Crop/ Source	Year	State	Number Affected	Species Affected	Certainty Index, Summary of Incident (Reference)
Sugarbeet[1]	1992	OR	5-10	Bald eagles	**Highly Probable/Possible Misuse**. Five bald eagle carcasses were collected in March, 1992 near Toulee Lake in the Klamath Basin Game Preserve, north of Klamath Falls OR. Analysis of the gut contents revealed terbufos residues. The gut content was mainly waterfowl. The source of the terbufos was not known. The report noted that sugar beet are grown in the Klamath Falls area and terbufos is registered on sugar beet. Ingestion of terbufos laced bovine meat as a poison bait was also speculated since the incident occurred prior to planting of sugar beet and the registrant does not have any records of sale in this area. (I000089-001; B0000-300-39, Bennett and Williams, 1996)

[1] Crop association if any is uncertain.

Table E-3. Summary of Aggregate Incident Data for Terbufos

Package and Sequence #	Incident From Date	Product Regulation #	Product Name	Formulation	Sum	Wildlife-Minor	Plant Damage-Minor	Other Non-Target
013492-00007	7/1/02 - 10/1/02	000241-00238	Counter 15G	Granular	1	0	1	0
013492-00006	7/1/02 - 10/1/02	000241-00314	Counter CR	Granular	4	0	4	0
012391-00006	7/1/01 - 10/31/01	000241-00314	Counter CR	Granular	1	0	1	0
010544-00007	5/1/00 - 7/31/00	000241-00314	Counter CR	Granular	1	1	0	0
010260-00001	6/1/00 - 6/30/00	000241-00238	Counter 15G systemic insecticide nematicide	Granular	1	1	0	0
010135-00001	1/1/00 - 4/30/00	000241-00238	Counter 15G systemic insecticide nematicide	Granular	3	3	0	0
008281-00006	9/1/98 - 11/30/98	000241-00241	Counter technical poison soil insecticide	Technical Chemical	1	1	0	0
008063-00002	7/1/98 - 9/30/98	000241-00314	Counter XL systemic insecticide nematicide	Granular	1	1	0	0
007883-00001	6/1/98 - 8/31/98	000241-00314	Counter XL systemic insecticide nematicide	Granular	1	1	0	0

NOTE: Incidents in the Aggregate Incident Database may duplicate reports in EIIS or AIMS.

Table E-4. Terbufos Incidents Identified in the Avian Incident Monitoring System (AIMS)[1]

Species	Pesticide(s)	Location	Year	Source(s)
Bald Eagle	Terbufos	Lancaster, NE	2002	FWSLE: Case 02-0330 FWSLE (INV): 2002602946
Green Jay Turkey Vulture	Terbufos	Nueces, TX	2001	FWSLE: Case 01-0268 FWSLE (INV): 2001201753
Cooper's Hawk	Terbufos	Burlington, NJ	2001	EIIS: I012549-007
European Starling, House Sparrow	Terbufos	Gratiot, MI	2000	MAHDL: 2226138 MIWDL: 000098 MIWDL: 000099 MIWDL: 000100 MIWDL: 000101 MIWDL: 000102 MIWDL: 000103 MIWDL: 000104
Canada Geese	Terbufos	Kent, DE	1997	EIIS: I007372-001
Eagle	Terbufos	Canada	1996	EIIS: I004605-001
Swainson's Hawk	Terbufos	King, TX	1996	EIIS: I003498-001
Bald Eagle	Terbufos	Pender, NC	1996	FWSLE: Case 96-0460 FWSLE (INV): 605000193
Red-tailed Hawk	Terbufos	Dane, WI	1995	EIIS: I002993-012 WAHL: 516215 WIDNR: 95-54
Passerine	Terbufos	Bonneville, ID	1994	FWSLE: Case 94-0490 FWSLE (INV): 1375AQ
Bald Eagle	Terbufos	Nuckolls, NE	1993	CWS: CWS93-8 FWSW: 11500-001
Bald Eagle	Terbufos	Nuckolls, NE	1993	CWS: CWS93-7 FWSW: 11497-002
Bald Eagle	Terbufos	Klamath, OR	1992	EIIS: B0000-300-39; I000089-001

NOTE: Incidents with an EIIS number are also listed above in **Table E-2**.

[1] Two incidents in the AIMS database associated with terbufos are also reported in the EIIS database and are considered to have been caused by other pesticides; therefore, they are not reported in **Table E-4**. An incident from 1998 is associated with phorate (EIIS: I002486-001) and another is from 1992 and is associated with carbofuran. (EIIS: I000799-007 and NC: IR92-72)

Appendix F: SWCC Input Parameters and Representative Sample Outputs

Table F-1. SWCC Input Parameters for Terbufos

Parameter	Input Value	Source	Comment
Application Rate	Corn: 1.30 lb a.i/A Sorghum: 1.68 lb ai/A Sugar beet: 1.98 lb a.i/A Corn: 2.6 lb a.i/A	EPA Reg# 241-314 EPA Reg# 5481-562 EPA Reg# SLN No. NC920001	Maximum application rates for specified crops based on the labels
Number of application/year	1	EPA Reg# 241-314 EPA Reg# 5481-562	Label directions
Application method	Incorporated	Current Labels	Label directions and to simulate subsurface incorporation of applied terbufos.
Depth of Incorporation	1 inch	Current labels	Label direction for corn. For sorghum and sugar beet, incorporation depths were assumed based on seeding depths
Use Site Scenario	**Corn** CA corn OP IA corn STD IL corn STD IN corn STD KS corn STD MN corn STD MS corn STD NC CornE STD NC CornW OP ND Corn OP NE corn STD OH corn STD PA corn STD TX corn OP FL sweetcorn OP OR Sweetcorn OP **Suger beet** CA Sugar Beet Wirrg OP MN Sugar Beet STD **Sorghum** KS Sorghum STD TX Sorghum OP	Label directions and available scenarios	The following scenarios were used in generating EECs: **Corn** 10 standard and 5 organo-phosphate specific scenarios **Suger beet** 1 standard and 1 organo-phosphate specific scenario **Sorghum** 1 standard and 1 organo-phosphate specific scenario
Application Date	Relative date: 7 days prior to emergence date in crop scenarios	Label Directions	---
Spray drift fraction	Not applicable	EFED Guidance (USEPA, 2013)	---
Molecular weight	288.4 g/mole	MRID 410449502	---

Parameter	Input Value	Source	Comment
Solubility in water (25 °C)	5.4 mg/L	MRID 410449502	---
Vapor pressure	3.16E-04 (mmHg @25°C)	MRID 410449502	---
Henry's Law constant (20 °C)	2.46E-05 atm.m^3 /mol	Footprint	
Hydrolysis ($t_{1/2}$)[1]	1.5 days @ 25°C @ pH 7	MRID 44862501	---
Aquatic photolysis ($t_{1/2}$)[1]	1.77 days	MRID 00161567 and 41181101	---
Aerobic soil metabolism ($t_{1/2}$)[1]	14.7 days	MRID 00156853 and 41749801	Based on 90% of the upper confidence limit (UCL) of the mean metabolism half-life (USEPA, 2009).
Aerobic aquatic metabolism ($t_{1/2}$)[1]	37.5 days	MRID 44672004	
Anaerobic aquatic metabolism ($t_{1/2}$)	Stable	---	Since terbufos is sensitive to hydrolytic degradation, anaerobic aerobic aquatic metabolism was assumed stable according to the Input Parameter Guidance (USEPA, 2009).
Partition coefficient K_d	11.11 mL/g	MRID 41373604	Mean K_d for 4 soils

[1] DT_{50s} were recalculated using NAFTA Guidance for Evaluating and Calculating Degradation Kinetics in Environmental Media (USEPA, 2012a). **Appendix A** contains revised estimated half-lives.

Table F-2. SWCC Input Parameters for Terbufos Sulfoxide

Parameter	Input Value	Source	Comment
Use Site and Scenarios Application Dates	*See* **Table 5** Relative Date: 30 days after terbufos application	**Table 5**	Application dates were adjusted based on maximum terbufos sulfoxide formation in laboratory studies.
Application Rate	Corn: 0.72 lb Corn: 1.44 lb (NC SLN 920001) Sorghum: 0.94 lb Sugar beet: 1.05 lb	Estimated	See sample calculations below[1]
Number of applications per year	1	EPA Reg# 241-314 EPA Reg# 5481-562	---
Application method	Ground	---	Degradation product of terbufos
Spray drift fraction	Not applicable	---	
Molecular weight	304.42 g/mole	EPISUITE 4.1	---
Solubility in water (25 °C)	3214 mg/L	MRID 44672001 and 44672002	Solubility of terbufos sulfoxide is higher than that of terbufos.
Vapor pressure	3.42E-05 (mmHg @25°C)	EPISUITE 4.1	

Parameter	Input Value	Source	Comment
Henry's Law constant (25 °C)	9.13E-08 atm.m^3 /mol	EPISUITE 4.1	Estimated using EPISUITE model
Hydrolysis ($t_{1/2}$)	65.1 days @ 25°C	MRID 44862501	---
Aquatic photolysis ($t_{1/2}$)	Stable	---	In absence of data, assumed stable according to the Input Parameter Guidance (USEPA, 2009)
Aerobic soil metabolism ($t_{1/2}$)	136 x 3 (408 days)	MRID 00156853	Single value is available. 3X was used according to the Input Parameter Guidance (USEPA, 2009)
Aerobic aquatic metabolism ($t_{1/2}$)	Stable	---	In absence of data, assumed stable
Anaerobic aquatic metabolism ($t_{1/2}$)	Stable	---	Since terbufos sulfoxide is sensitive to hydrolytic degradation, anaerobic aerobic aquatic metabolism was assumed stable according to the Input Parameter Guidance (USEPA, 2009)
Partition coefficient K_d	1.12 mL/g	MRID 41373604	Mean K_d for 4 soils

[1]Terbufos sulfoxide application rate = terbufos application rate of 1.30 lb x (0.523, the maximum conversion rate from the degradation of terbufos to terbufos sulfoxide in laboratory studies) x (1.055, the molecular weight ratio of terbufos sulfoxide to terbufos.

Table F-3. SWCC Input Parameters for Terbufos Sulfone

Parameter	Input Value	Source	Comment
Use Site and Scenarios Application Dates	*See* **Table 5** Relative Date: 60 days after terbufos application	**Table 5**	Application dates were adjusted based on maximum terbufos sulfone formation in the laboratory studies.
Application Rate	Corn: 0.29 lb Corn: 0.58 lb (NC SLN 920001) Sorghum: 0.38 lb Sugar beet: 0.44 lb	Estimated	See a sample calculations below[1]
Number of applications per year	1	EPA Reg # 241-314 EPA Reg# 5481-562	
Application method	Ground	---	Degradation product of terbufos
Spray drift fraction	Not applicable	---	
Molecular weight	320.42 g/mole	EPISUITE 4.1	---
Solubility in water (25 °C)	407 mg/L	MRID 44672001 and 44672002	Terbufos sulfone is more soluble than terbufos
Vapor pressure	7.88E-06 (mmHg @25°C)	EPISUITE 4.1	Estimated using EPISUITE model
Henry's Law constant (25 °C)	4.10E-08 atm.m^3 /mol	EPISUITE 4.1	

Parameter	Input Value	Source	Comment
Hydrolysis ($t_{1/2}$)	43.8 days @ 25°C	MRID 44862501	---
Aquatic photolysis ($t_{1/2}$)	Stable	---	Assumed stable
Aerobic soil metabolism ($t_{1/2}$)	174 x 3 (522 days)	MRID 00156853	Single value is available. 3X was used according to the Input Parameter Guidance (USEPA, 2009)
Aerobic aquatic metabolism ($t_{1/2}$)	Stable	----	In absence of data, assumed stable according to the Input Parameter Guidance (USEPA, 2009)
Anaerobic aquatic metabolism ($t_{1/2}$)	Stable	---	Since terbufos sulfoxide is sensitive to hydrolytic degradation, anaerobic aerobic aquatic metabolism is assumed stable according to the Input Parameter Guidance (USEPA, 2009)
Partition coefficient K_d	1.26 mL/g	MRID 41373604	Mean K_d for 4 soils

[1]Terbufos sulfone application rate = terbufos application rate of 1.30 lb x (0.201, the maximum conversion rate from the degradation of terbufos to terbufos sulfone in laboratory studies) x (1.11, the molecular weight ratio of terbufos sulfone to terbufos.

Table F-4. SWCC EECs for Terbufos, Terbufos Sulfoxide and Terbufos Sulfone for Various Crop Scenarios and Application Rates

Scenarios	Surface Water					Pore Water	
	Peak	4-day	21-day	60-day	90-day	Peak	21-day
	Concentration (µg/L)						
Terbufos (Corn/Sweetcorn)							
IAcornstd	7.06	2.81	0.63	0.23	0.16	5.14	3.88
ILCornSTD	7.79	3.07	0.95	0.35	0.23	3.88	3.23
INCornStd	7.44	3.25	0.93	0.34	0.23	1.83	1.47
KSCornStd	8.98	3.92	1.27	0.46	0.31	1.96	1.59
MNCornStd	5.87	2.28	0.49	0.18	0.12	1.36	1.09
MScornSTD	17.30	8.92	2.44	0.90	0.60	11.30	8.74
NCcornESTD	4.76	2.34	0.54	0.19	0.13	1.29	1.04
NECornStd	11.90	5.39	1.45	0.57	0.38	3.85	3.15
OHCornSTD	9.31	4.21	1.00	0.41	0.28	6.58	5.03
PAcornSTD	3.29	1.36	0.41	0.15	0.10	0.77	0.62
CAcornOP	1.71	0.68	0.15	0.05	0.04	0.52	0.41
FLsweetcornOP	11.50	4.22	1.03	0.47	0.69	0.46	0.38
NCcornWOP	3.86	1.65	0.40	0.16	0.11	0.42	0.35
NDcornOP	1.50	0.76	0.18	0.07	0.05	0.21	0.17
ORswcornOP	1.28	0.54	0.13	0.05	0.03	0.44	0.34

Scenarios	Surface Water					Pore Water	
	Peak	4-day	21-day	60-day	90-day	Peak	21-day
	Concentration (µg/L)						
TXcornOP	4.18	1.56	0.38	0.14	0.10	1.32	1.04
2X Application Rate for North Carolina							
NCcornWOP	10.60	4.80	1.18	0.44	0.30	1.51	1.25
NCcornESTD	12.50	5.07	1.11	0.43	0.29	2.10	1.74
Terbufos Sulfoxide (Corn/Sweetcorn)							
IAcornstd	3.52	3.45	3.21	2.66	2.33	1.59	1.58
ILCornSTD	8.62	8.43	7.74	6.68	6.07	5.39	5.37
INCornStd	4.96	4.85	4.46	3.75	3.26	2.20	2.19
KSCornStd	15.90	15.60	14.50	12.20	10.70	7.33	7.30
MNCornStd	6.46	6.32	5.96	4.97	4.33	2.90	2.89
MScornSTD	17.00	16.60	15.80	13.40	11.70	12.70	12.70
NCcornESTD	4.26	4.16	3.84	3.18	2.77	1.97	1.96
NECornStd	11.20	10.90	10.10	8.38	7.34	5.05	5.05
OHCornSTD	7.32	7.16	6.55	5.41	4.70	3.78	3.77
PAcornSTD	4.53	4.43	4.14	3.40	2.96	2.27	2.26
CAcornOP	4.92	4.81	4.43	3.65	3.17	2.17	2.16
FLsweetcornOP	26.40	26.40	25.00	24.50	21.20	14.30	14.10
NCcornWOP	11.30	11.10	10.20	8.55	7.46	5.04	5.02
NDcornOP	5.78	5.65	5.15	4.21	3.66	2.45	2.44
ORswcornOP	1.96	1.93	1.78	1.52	1.61	1.09	1.09
TXcornOP	15.80	15.40	14.10	11.70	10.20	7.18	7.15
2X Application Rate for North Carolina							
NCcornWOP	22.70	22.30	20.30	17.10	14.90	10.10	10.00
NCcornESTD	8.52	8.33	7.68	6.36	5.54	3.94	3.92
Terbufos Sulfone (Corn/Sweetcorn)							
IAcornstd	3.93	3.80	3.48	2.67	2.22	1.70	1.70
ILCornSTD	4.87	4.71	4.33	3.59	3.01	2.59	2.57
INCornStd	4.61	4.46	4.03	3.07	2.54	1.69	1.68
KSCornStd	4.55	4.47	4.18	3.29	2.74	1.88	1.86
MNCornStd	4.20	4.07	3.63	2.85	2.47	1.75	1.74
MScornSTD	5.55	5.37	4.74	3.61	2.98	2.29	2.27
NCcornESTD	3.97	3.85	3.43	2.65	2.20	1.56	1.55
NECornStd	7.57	7.32	6.41	5.02	4.21	2.93	2.93
OHCornSTD	3.70	3.62	3.18	2.40	1.98	1.33	1.32
PAcornSTD	2.43	2.35	2.08	1.60	1.33	0.91	0.90
CAcornOP	1.95	1.92	1.99	1.65	1.35	0.92	0.91
FLsweetcornOP	4.78	4.63	4.43	2.67	2.21	1.61	1.44
NCcornWOP	4.23	4.09	3.59	2.75	2.29	1.56	1.55

Scenarios	Surface Water					Pore Water	
	Peak	4-day	21-day	60-day	90-day	Peak	21-day
	Concentration (µg/L)						
NDcornOP	4.30	4.16	3.64	2.74	2.26	1.50	1.49
ORswcornOP	2.22	2.17	1.95	1.73	1.42	0.96	0.95
TXcornOP	10.10	9.77	8.58	6.52	5.39	4.36	4.34
2X Application Rate for North Carolina							
NCcornWOP	9.76	9.44	8.29	6.36	5.28	3.59	3.57
NCcornESTD	9.16	8.88	7.91	6.13	5.07	3.61	3.58
Terbufos (Sorghum)							
KSsorghumSTD	7.75	3.11	0.73	0.33	0.22	2.57	1.98
TXSorghumOP	19.10	7.64	1.80	0.66	0.44	10.8	8.41
Terbufos Sulfoxide (Sorghum)							
KSsorghumSTD	10.50	10.20	9.54	8.13	7.11	5.25	5.22
TXSorghumOP	23.90	23.30	21.50	18.30	16.00	11.00	10.90
Terbufos Sulfone (Sorghum)							
KSsorghumSTD	4.55	4.43	3.91	3.00	2.48	1.70	1.69
TXSorghumOP	6.52	6.31	5.55	4.21	3.50	2.56	2.56
Terbufos (Sugar bee							
MNSugarbeetSTD	5.62	2.51	0.59	0.21	0.15	1.57	1.26
CASugarbeetwirrgOP	4.14	1.83	0.57	0.21	0.20	0.48	0.41
Terbufos Sulfoxide (Sugar beet)							
MNSugarbeetSTD	7.89	7.71	7.07	5.93	5.92	3.99	3.98
CASugarbeetwirrgOP	9.18	8.98	8.27	6.87	6.00	4.21	4.20
Terbufos Sulfone (Sugar beet)							
MNSugarbeetSTD	4.24	4.10	3.66	2.86	2.37	1.58	1.57
CASugarbeetwirrgOP	0.89	0.86	0.77	0.59	0.49	0.32	0.32

Table F-5. Total Toxic Residue in Water Column: TX Sorghum Scenario

Year	Max Peak	4-day	Max 14 day	Max 21 day	Max 30 day	Max 60 day	Max 90 day	Annual
1961	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1962	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
1965	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.00
1966	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1967	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1968	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1969	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
1970	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.00

Year	Max Peak	4-day	Max 14 day	Max 21 day	Max 30 day	Max 60 day	Max 90 day	Annual
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1973	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
1974	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1975	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.01
1976	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.02
1977	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02
1978	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
1979	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1980	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
1981	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1982	0.04	0.02	0.02	0.02	0.02	0.02	0.01	0.01
1983	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01
1987	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
1988	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1990	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
90th% (ppm)	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01
90th% (ppb)	35.74	24.19	22.47	21.90	21.18	18.47	16.28	8.86

Table F-6. Total Toxic Residue in Benthic Layer: TX Sorghum Scenario

Year	Max Peak	4-day	Max 14 day	Max 21 day	Max 30 day	Max 60 day	Max 90 day	Annual
1961	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.00
1962	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1963	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1964	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1966	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1969	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1970	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1971	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Year	Max Peak	4-day	Max 14 day	Max 21 day	Max 30 day	Max 60 day	Max 90 day	Annual
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1982	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
1983	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90th %(ppm)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
90th % (ppb)	12.46	12.41	12.15	11.44	10.30	7.40	6.98	3.90

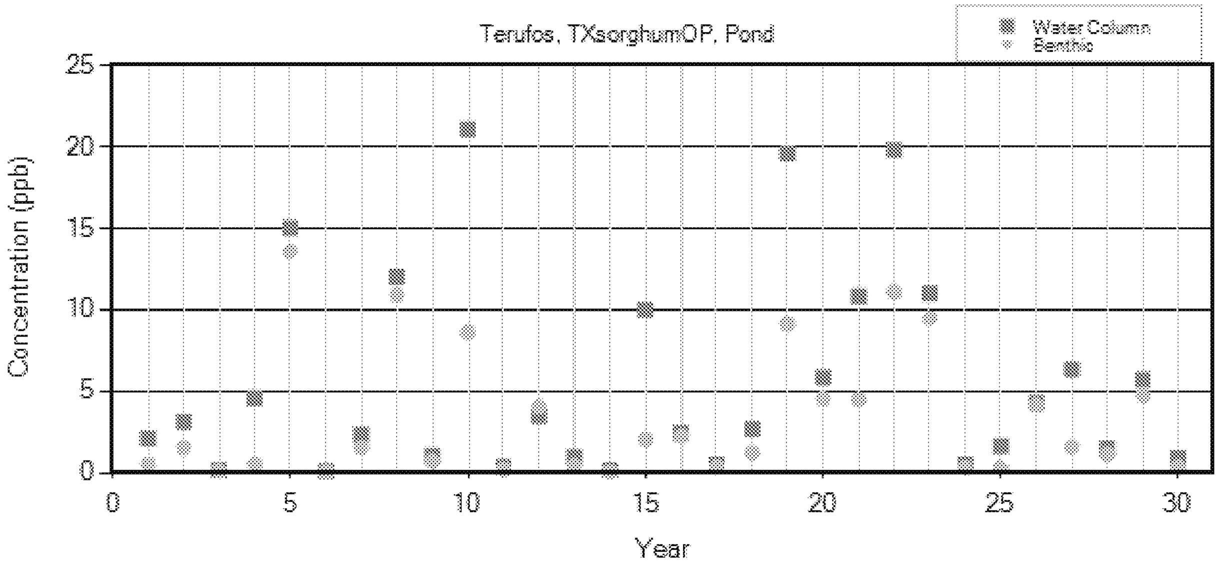
Summary of Water Modeling of Terbufos and the USEPA Standard Pond

Estimated Environmental Concentrations for terbufos are presented in **Table F-7** for the USEPA standard pond with the TXsorghumOP field scenario. A graphical presentation of the year-to-year peaks is presented in **Figure F-1**. These values were generated with the Surface Water Concentration Calculator (SWCC Version 1.106).

Table F-7. Estimated Environmental Concentrations (ppb) for Terbufos

Peak (1-in-10 yr)	19.1
4-day Avg (1-in-10 yr)	7.64
21-day Avg (1-in-10 yr)	1.80
60-day Avg (1-in-10 yr)	0.662
365-day Avg (1-in-10 yr)	0.111
Entire Simulation Mean	0.426E-01

Figure F-1. Yearly Peak Concentrations



Appendix G: Representative T-REX Input and Output

Scenario: Corn, 7 inch band at planting, 1.3 lb ai/A (0.075 lb ia/1000 ft row), toxicity based on TGAI

Table G-1. Input

Application Rate	1.3	lb / acre
% AI	100.00%	
Avian LD50 (20g)	20.60	mg/kg bw
(100g)	26.23	
(1000g)	37.05	
Mammalian LD50 (15g)	2.75	mg/kg bw
(35g)	2.22	
(1000g)	0.96	
Row Spacing	30	inches
Bandwidth	7	inches
Unincorporation	15%	

Table G-2. Output and Calculations

	# rows acre-1	83.48
	row length (ft)	208.71
	lb ai/1000 ft row	0.075
	bandwidth (ft)	0.58
	mg ai/ft2	58.02
	exposed mg ai/ft2	8.70
	wgt class (grams)	**Acute RQ LD_{50}/ft^2**
Avian	**20**	21.12
	100	3.32
	1000	0.23
Mammal	**15**	211.17
	35	111.85
	1000	9.05

Chronic RQs were calculated based on the ratio of exposed mg ai/ft2 to dose-based NOAEL (mg ai/kg bw).

The avian dietary-based chronic toxicity value (NOAEC = 5 mg ai/kg diet; MRID 0161574) was converted to a dose equivalent toxicity value. mg ai/kg bw = (mg ai/kg diet * daily food intake)/kg bw. daily food intake = 0.0582 * bw^0.651 (source: SIP v 1.0 manual). bw = 1.136 kg (source: mean value from MRID 0161574). NOAEL= 0.278 mg ai/kg bw = (5 mg ai/kg diet * 0.632 kg/day)/1.136 kg bw

Appendix H: Representative KABAM Input

Scenario: Corn (1.3 lb ai/A), crop scenario: MScorn_STD

Table H-1. Chemical Characteristics of Terbufos

Characteristic	Value	Comments/Guidance[1]
Pesticide Name	Terbufos	
Log K_{OW}	4.71	Enter value from acceptable or supplemental study submitted by registrant or available in scientific literature.
K_{OW}	51286	No input necessary. This value is calculated automatically from the Log K_{OW} value entered above.
K_{OC} (L/kg OC)	17950	Input value used in PRZM/EXAMS to derive EECs. Follow input parameter guidance for deriving this parameter value (USEPA, 2009).
Time to steady state (T_S; days)	16	No input necessary. This value is calculated automatically from the Log K_{OW} value entered above.
Pore water EEC (µg/L)	8.74	Enter value generated by PRZM/EXAMS benthic file. PRZM/EXAMS EEC represents the freely dissolved concentration of the pesticide in the pore water of the sediment. The appropriate averaging period of the EEC is dependent on the specific pesticide being modeled and is based on the time it takes for the chemical to reach steady state. Select the EEC generated by PRZM/EXAMS which has an averaging period closest to the time to steady state calculated above. In cases where the time to steady state exceeds 365 days, the user should select the EEC representing the average of yearly averages. The peak EEC should not be used.
Water Column EEC (µg/L)	2.44	Enter value generated by PRZM/EXAMS water column file. PRZM/EXAMS EEC represents the freely dissolved concentration of the pesticide in the water column. The appropriate averaging period of the EEC is dependent on the specific pesticide being modeled and is based on the time it takes for the chemical to reach steady state. The averaging period used for the water column EEC should be the same as the one selected for the pore water EEC (discussed above).

[1] SWCC is the current model.

Table H-2. Input Parameters for Rate Constants

Trophic level	k_1 (L/kg*d)	k_2 (d^{-1})	k_D (kg-food/kg-org/d)	k_E (d^{-1})	k_M* (d^{-1})
phytoplankton	calculated	calculated	0*	0*	0
zooplankton	calculated	calculated	calculated	calculated	0
benthic invertebrates	calculated	calculated	calculated	calculated	0
filter feeders	calculated	calculated	calculated	calculated	0
small fish	calculated	calculated	calculated	calculated	0
medium fish	calculated	calculated	calculated	calculated	0
large fish	calculated	calculated	calculated	calculated	0

* Default value is 0.
k_1 and k_2 represent the uptake and elimination constants, respectively, through respiration.
k_D and k_E represent the uptake and elimination constants, respectively, through diet.
k_M represents the metabolism rate constant.

Table H-3. Mammalian and Avian Toxicity Data for Terbufos

Animal	Measure of effect (units)	Value	Comment
Avian	LD_{50} (mg/kg bw)	28.6	Northern bobwhite quail
	LC_{50} (mg/kg-diet)	143	Northern bobwhite quail
	NOAEC (mg/kg-diet)	5	Mallard duck
	Mineau Scaling Factor	1.15	Default value
Mammalian	LD_{50} (mg/kg bw)	1.25	Laboratory rat
	NOAEC (mg/kg-diet)	1	Laboratory rat

Appendix I: STIR Input and Output

Scenario: Corn – use with the lowest maximum application rate (1.3 lb ai/A)

Table I-1. Inputs

Enter Chemical Use	Outdoor
Is the Application a Spray?	No
Enter Chemical Molecular Weight (g/mole)	288.4
Enter Chemical Vapor Pressure (mmHg)	3.16E-04
Enter Application Rate (lb ai/A)	1.3
Toxicity Properties	
Bird	
Enter Lowest Bird Oral LD_{50} (mg/kg bw)	28.6
Enter Mineau Scaling Factor	1.15
Enter Tested Bird Weight (kg)	0.178
Mammal	
Enter Lowest Rat Oral LD_{50} (mg/kg bw)	1.25
Enter Lowest Rat Inhalation LC_{50} (mg/L)	0.0012
Duration of Rat Inhalation Study (hrs)	4
Enter Rat Weight (kg)	0.35

Table I-2. Avian Results (0.020 kg)

Maximum Vapor Concentration in Air at Saturation (mg/m^3)	4.90E+00
Maximum 1-hour Vapor Inhalation Dose (mg/kg)	6.17E-01
Adjusted Inhalation LD_{50}	1.53E-01
Ratio of Vapor Dose to Adjusted Inhalation LD_{50}	4.03E+00

Table I-3. Mammalian Results (0.015 kg)

Maximum Vapor Concentration in Air at Saturation (mg/m^3)	4.90E+00
Maximum 1-hour Vapor Inhalation Dose (mg/kg)	7.75E-01
Adjusted Inhalation LD_{50}	7.14E-02
Ratio of Vapor Dose to Adjusted Inhalation LD_{50}	1.08E+01

Appendix J: SIP Input and Output

SIP employs the following conservative assumptions to derive upper bound exposure estimates:
1) The chemical concentration in drinking water is at the solubility limit in water (at 25°C).
2) The assessed animals obtain 100% of their daily water needs through drinking water.
3) The daily water need is equivalent to the daily water flux rate as calculated by Nagy and Peterson (1988).
4) The body weight of the assessed bird is equivalent to the smallest generic bird modeled in T-REX (i.e., 20 g). This assumption results in the highest ratio of exposure to toxicity for the 3 assessed avian body weights of T-REX (i.e., 20, 100, 1000 g).
5) The body weight of the assessed mammal is equivalent to the largest generic mammal modeled in T-REX (i.e., 1000 g). This results in the highest ratio of exposure to toxicity for the 3 assessed mammalian body weights of T-REX (i.e., 15, 35, 1000 g).

Table J-1. Inputs

Parameter	Value
Chemical name	Terbufos
Solubility (in water at 25°C; mg/L)	5.4
Mammalian LD_{50} (mg/kg bw)	1.25
Mammalian test species	Laboratory rat
Mammalian NOAEL (mg/kg bw)	0.07
Mammalian test species	Laboratory rat
Avian LD_{50} (mg/kg bw)	28.6
Avian test species	Northern bobwhite quail
Mineau scaling factor	1.15
Mallard NOAEC (mg/kg-diet)	5
Bobwhite quail NOAEC (mg/kg-diet)	30

Table J-2. Mammalian Results

Parameter	Acute	Chronic
Upper bound exposure (mg/kg bw)	0.9288	0.9288
Adjusted toxicity value (mg/kg bw)	0.9615	0.0538
Ratio of exposure to toxicity	0.9660	17.2507
Conclusion	**Exposure through drinking water alone is a potential concern for mammals**	**Exposure through drinking water alone is a potential concern for mammals**

Table J-3. Avian Results

Parameter	Acute	Chronic
Upper bound exposure (mg/kg bw)	4.3740	4.3740
Adjusted toxicity value (mg/kg bw)	20.6043	0.2481
Ratio of exposure to acute toxicity	0.2123	17.6326
Conclusion	**Exposure through drinking water alone is a potential concern for birds**	**Exposure through drinking water alone is a potential concern for birds**

APPENDIX K: TerrPlant Input and Output (NC use on corn)

Table K-1. Chemical Identity

Chemical Name	Terbufos
PC code	105001
Use	Corn (NC supplemental label)
Application Method	Banded
Application Form	Granular
Solubility in Water (ppm)	5.4

Table K-2. Input Parameters Used to Derive EECs

Input Parameter	Symbol	Value	Units
Application Rate	A	2.6	lb ai/A
Incorporation	I	1	none
Runoff Fraction	R	0.01	none
Drift Fraction	D	0	none

Table K-3. EECs for Terbufos (lb ai/A)

Description	Equation	EEC
Runoff to dry areas	(A/I)*R	0.026
Runoff to semi-aquatic areas	(A/I)*R*10	0.26
Spray drift	A*D	0
Total for dry areas	((A/I)*R)+(A*D)	0.026
Total for semi-aquatic areas	((A/I)*R*10)+(A*D)	0.26

Table K-4. Plant Survival and Growth Data Used for RQ Derivation. Units are in lb ai/A

Plant type	Seedling Emergence		Vegetative Vigor	
	EC_{25}	NOAEC	EC_{25}	NOAEC
Monocot	ND	2	ND	ND
Dicot	ND	2	ND	ND

Table K-5. RQ Values for Plants in Dry and Semi-Aquatic Areas Exposed to Terbufos Through Runoff.*

Plant Type	Listed Status	Dry	Semi-Aquatic	Spray Drift
Monocot	non-listed	N/A	N/A	N/A
Monocot	listed	<0.1	0.13	N/A
Dicot	non-listed	N/A	N/A	N/A
Dicot	listed	<0.1	0.13	N/A

*If RQ > 1.0, the LOC is exceeded, resulting in potential for risk to that plant group.

ND = no data
N/A = not applicable

Appendix L: Characterization of Avian and Mammal Risk from Consuming Terbufos Granules

Table L-1. Characterization of Avian Risk from Consuming Terbufos Granules[1]

Use	Application Method (% incorporation)	lb ai/1000 ft row	Product	Band width (in)	Row Spacing (in)	Exposed mg ai/ft^2	# Exposed Granules/ ft^2 [(2)]	Toxicity (form)[3]	# granules to exceed acute LOC[4]					
									0.02 kg bird		0.1 kg bird		1 kg bird	
									LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1
Corn	Banded, at planting (85%)	0.15	15G (NC)	7	30	17.4	637-1758	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
		0.075	CR			8.7	51	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				319-879	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G	5		12.18	381	TGAI	6	1	41	8	579	116
				4		15.23	476							
	In furrow, at planting (99%)	0.15	15G (NC)	1		8.12	297-820	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
		0.075	CR			4.06	24	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				149-410	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G				127	TGAI	6	1	41	8	579	116
	Banded, postemergence and at cultivation (85%)	0.075	CR	7		8.7	51	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				319-879	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G				272	TGAI	6	1	41	8	579	116

Use	Application Method (% incorporation)	lb ai/1000 ft row	Product	Band width (in)	Row Spacing (in)	Exposed mg ai/ft^2	# Exposed Granules/ ft^2 (2)	Toxicity (form)[3]	# granules to exceed acute LOC[4]					
									0.02 kg bird		0.1 kg bird		1 kg bird	
									LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1
Sorghum	Knifed in, at bedding and at planting (99%)	0.065	CR	1	20	3.5	21	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
		0.066	15G			3.53	129-357	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
		0.065	20G			3.5	109	TGAI	6	1	41	8	579	116
	Banded, at planting (85%)	0.065	CR	7		7.5	44	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
		0.066	15G			7.56	277-764	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
		0.065	20G			7.5	234	TGAI	6	1	41	8	579	116
		0.066	15G	5		10.59	388-1070	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
		0.065	20G			10.5	328	TGAI	6	1	41	8	579	116

Use	Application Method (% incorporation)	lb ai/1000 ft row	Product	Band width (in)	Row Spacing (in)	Exposed mg ai/ft^2	# Exposed Granules/ ft^{2} (2)	Toxicity (form)[3]	# granules to exceed acute LOC[4]					
									0.02 kg bird		0.1 kg bird		1 kg bird	
									LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1
Sugar beet	Modified in furrow and knifed in, at planting (99%)	0.075	CR	1	20	4.08	24	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				149-412	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G				128	TGAI	6	1	41	8	579	116
	Banded, at planting and postemergence (85%)		CR	7		8.75	51	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				321-884	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G				273	TGAI	6	1	41	8	579	116
			CR	5		12.25	72	TGAI	1	<1	8	2	109	22
								CR	1	<1	6	1	78	16
			15G				449-1237	TGAI	8-21	2-4	48-132	10-27	679-1871	136-374
								15G	3-7	1-2	16-44	3-9	226-623	45-125
			20G				383	TGAI	6	1	41	8	579	116

[1] Product application methods (timing, lb ai/ft row, band width, and row width) were obtained from the most recent product labels.
[2] Based on the following granule weights: CR = 0.85 mg/granule (source: American Cyanamid as reported in USEPA, 1999); 20G = 0.16 mg/granule (source: email from AMVAC dated 3/3/14); 15G = 0.066-0.182 mg/granule (source: Hill and Camardese, 1984 and MRID 41508803 & 41508805). # exposed granules/ft^2 = exposed mg ai/ft^2/(granule weight as mg * % ai)
[3] Toxicity based on TGAI, Bobwhite quail LD_{50} = 28.6 mg ai/kg/bw; 15G, Mallard duck LD_{50} = 13.21 mg ai/kg bw; CR, Cowbird LD_{50} = 16.9 mg ai/kg bw
[4] Number of granules rounded to nearest whole number.

Table L-2. Characterization of Mammalian Risk from Consuming Terbufos Granules[1]

Use	Application Method (% incorporation)	lb ai/ 1000 ft row	Product	Band width (in)	Row Spacing (in)	Exposed mg ai/ft^2	# Exposed Granules/ ft^2 [(2)]	Toxicity (form)[3]	# granules to exceed acute LOC[4] 0.015 kg[5]		0.035 kg[5]		1 kg[5]	
									LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1
Corn	Banded, at planting (85%)	0.15	15G (NC)	7	30	17.4	637-1758	TGAI	<1-2	<1	1-4	<1	18-49	4-10
		0.075	CR			8.7	51	TGAI	<1	<1	<1	<1	3	<1
			15G				319-879		<1-2	<1	1-4	<1	18-49	4-10
			20G	5		12.18	381	TGAI	<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
				4		15.23	476	TGAI	<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
	In furrow, at planting (99%)	0.15	15G (NC)	1		8.12	297-820	TGAI	<1-2	<1	1-4	<1	18-49	4-10
		0.075	CR			4.06	24	TGAI	<1	<1	<1	<1	3	<1
			15G				149-410		<1-2	<1	1-4	<1	18-49	4-10
			20G				127		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
	Banded, postemergence and at cultivation (85%)	0.075	CR	7		8.7	51	TGAI	<1	<1	<1	<1	3	<1
			15G				319-879		<1-2	<1	1-4	<1	18-49	4-10
			20G				272		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
Sorghum	Knifed in, at bedding and at planting (99%)	0.065	CR	1	20	3.5	21	TGAI	<1	<1	<1	<1	3	<1
		0.066	15G			3.53	129-357		<1-2	<1	1-4	<1	18-49	4-10
		0.065	20G			3.5	109		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
	Banded, at planting (85%)	0.065	CR	7		7.5	44	TGAI	<1	<1	<1	<1	3	<1
		0.066	15G			7.56	277-764		<1-2	<1	1-4	<1	18-49	4-10
		0.065	20G			7.5	234		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
		0.066	15G	5		10.59	388-1070	TGAI	<1-2	<1	1-4	<1	18-49	4-10
		0.065	20G			10.5	328		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2

Use	Application Method (% incorporation)	lb ai/ 1000 ft row	Product	Band width (in)	Row Spacing (in)	Exposed mg ai/ft²	# Exposed Granules/ ft² [(2)]	Toxicity (form)[3]	# granules to exceed acute LOC[4]					
									0.015 kg[5]		0.035 kg[5]		1 kg[5]	
									LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1	LOC = 0.5	LOC = 0.1
Sugar beet	Modified in furrow and knifed in, at planting (99%)	0.075	CR	1	20	4.08	24	TGAI	<1	<1	<1	<1	3	<1
			15G				149-412		<1-2	<1	1-4	<1	18-49	4-10
			20G				128		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
	Banded, at planting and postemergence (85%)		CR	7		8.75	51	TGAI	<1	<1	<1	<1	3	<1
			15G				321-884		<1-2	<1	1-4	<1	18-49	4-10
			20G				273		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2
			CR	5		12.25	72	TGAI	<1	<1	<1	<1	3	<1
			15G				449-1237		<1-2	<1	1-4	<1	18-49	4-10
			20G				383		<1	<1	1	<1	15	3
								20G	<1	<1	<1	<1	10	2

[1] Product application methods (timing, lb ai/ft row, band width, and row width) were obtained from the most recent product labels.
[2] Based on the following granule weights: CR = 0.85 mg/granule (source: American Cyanamid as reported in USEPA 1999); 20G = 0.16 mg/granule (source: email from AMVAC dated 3/3/14); 15G = 0.066-0.182 mg/granule (source: Hill and Camardese, 1984 and MRID 41508803 & 41508805). # exposed granules/ft² = exposed mg ai/ft²/(granule weight as mg * % ai)
[3] Toxicity based on TGAI, Rat LD_{50} = 1.25 mg ai/kg/bw; 20G, rat LD_{50} = 0.836 mg ai/kg bw
[4] Number of granules rounded to nearest whole number.
[5] Mammal body weight

Appendix M: ECOTOXicology Database References

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